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TECHNICAL MEMORANDUM

THE DEVELOPMENT OF A GENERAL COMBAT SIMULATION MODEL

by

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8 September 1967

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ABSTRACT

In the first portion of this Technical Memorandum, the general approach to the complete digital computer simulation of Anti-Submarine Warfare (ASW) Combat is formulated and discussed. The discussion centers upon the three basic components of combat- command and control functions, machines and the environment- and identifies the general parameters and dynamic variables required to simulate these components. (While the primary concern is ASW combat, the general principles are applicable to any type of combat). The second portion of this memorandum presents a detailed description of the simulation of marine combat between two submarines. In this simulation one submarine is deployed on a Forward Area Patrol Mission. The mission of the second submarine is to transit the patrol area of the first submarine. This digital computer simulation contains many features discussed in the general approach and demonstrates the feasibility of constructing a general ASW Combat Simulation for a digital computer.

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1. INTRODUCTION

Technological progress in recent years has made possible the creation of highly sophisticated military systems. Continuing technological progress during the foreseeable future will make even more sophisticated systems possible. The experimental evaluation of existing systems and their role in combat is both expensive and time consuming. The experimental evaluation of proposed systems and their role in combat is not possible. Thus, accurate analytical techniques for the rapid evaluation of the effectiveness of military systems, and their employment, are required.

To accurately analyze military systems and their role in combat, it is necessary to address the complete problem. When modern complex military systems are considered, digital computer simulation is the most promising method of rapidly addressing the complete problem. In the past, analytical studies without the aid of a digital computer have been useful in the analysis of effectiveness and the determination of optimum employment of military systems. As these systems have become more complex, however, the results obtained by these studies have become questionable. A single such study can consider only a few facets, frequently only one, of a realistic engagement. Furthermore, the few aspects of the problem that are considered may not conform to reality because of simplifying assumptions required to yield a tractable problem.

It is now possible to construct a dynamic, three-dimensional, digital computer simulation of combat which addresses the complete problem. In this simulation, the dynamic in-situ performance of all relevant subsystems and weapons possessed by each participant can be reproduced with an accuracy commensurate with the current state of understanding of these elements. Each participant in the simulation can be provided with a command and control function which accurately reproduces the performance of that participant's decision maker.

Once constructed, such a model would provide a tool for realistically assessing the impact on mission effectiveness of both subsystem and weapon performance and tactics. Furthermore, the model can be constructed so as to permit the rapid assessment, in terms of mission effectiveness, of the effects of changes in system performance parameters, changes in the tactics employed by the participants, and/or changes in environmental conditions.

The purpose of this technical memorandum is two-fold. First, the general problem of the development and use of a digital computer simulation of ASW combat is discussed. This discussion is contained in Chapters 2 and 3 where the general principles for combat simulation are set forth, the general problems associated with sonar system simulation are identified, and an approach to the solution of these problems is outlined.

The second purpose of this technical memorandum is to present a detailed description of a digital computer program prepared to simulate the engagement between two submarines. This particular simulation was prepared to assist in evaluating the effectiveness of certain sonar subsystems proposed for installation in the Post World War II diesel-electric attack submarines and in the pre-SKIPJACK nuclear attack submarines. This computer simulation is important for two reasons. It demonstrates the feasibility of simulating a combat situation, and the results of the simulation can materially aid in the evaluation of the effectiveness of the subsystems in question. Chapter 4 contains a detailed discussion of the factors considered in the two-submarine combat simulation. Sample results obtained by exercising this model are presented in Chapter 5. Chapter 6 discusses problem areas encountered in the current simulation and those anticipated to occur in the expansion of the current model into a general ASW combat simulation model.

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2. THE PURPOSE OF ASW COMBAT SIMULATION

The purpose of combat simulation is to provide a tool for the evaluation of mission effectiveness in terms of the relevant system, tactical, and operational parameters. The question of mission effectiveness is fundamental in each of the following types of analyses:

(a) The analysis of real or hypothetical military systems in given situations for specific tactical doctrines;

(b) The analysis of real or hypothetical tactical doctrines in given situations for specific military systems;

(c) The analysis of both tactical doctrine and military system requirements necessary to accomplish particular types of missions.

A single digital computer simulation, properly constructed, can provide the means of performing any of these analyses. A detailed discussion of the principles involved in the construction of such a simulation is the subject of the next chapter and only the basic features will be given here. Basically, the simulation of combat involves the simulation of the actions of all participants involved, both friendly and enemy. The simulated action of each participant is governed by the simulated performance of all relevant information subsystems and weapons possessed by that participant, by the simulated performance of the participant's vehicle, and by a simulated command and control function. The tactics employed by each participant are incorporated into that participant's command and control function. The performance of all subsystems and weapons is simulated in terms of the subsystem and weapon performance parameters and the dynamic and environmental variables affecting performance. Finally, to be useful, the model must be amenable to rapid alteration of number of participants, tactics employed, subsystem and weapon performance, and character of the dynamic and environmental variables.

To use the simulation model in any one of the three types of analysis, one specifies:

1. the mission to be simulated;
2. the participants, both friendly and enemy;
3. the initial positions of each participant;
4. the subsystems and weapons possessed by each participant;
5. the tactics to be employed by each participant, and
6. the environment.

The model is then exercised to simulate the course of the engagement from initial encounter to conclusion. The exercise of the simulation reproduces the evolution of the engagement as well as the ultimate result. Thus, the effects of tactics, subsystem and weapon performance parameters, etc., upon mission effectiveness of all of the participants can be ascertained and analyzed.

The simulation of one engagement would seldom provide sufficient information for a system or tactical analysis. One would generally exercise the model many times, holding constant those parameters to be evaluated while varying the other parameters of the engagement over a reasonable range of values.

A specific example of the use of the model will now be considered. A frequent measure of mission effectiveness is kill probability. If it were desired to evaluate the effectiveness of several different sonar systems, and if kill probability were the measure of mission effectiveness, one would proceed as follows:

(a) Provide a typical vessel with the simulated performance of one of the candidate systems;

(b) Repeatedly exercise the combat model for relevant combinations of:

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(1) missions,

(2) number of participants,

(3) subsystems of other participants,

(4) tactics of all participants,

(5) geographic regions of encounter,

(6) geometries of encounter,

(7) other dynamic variables;

(c) Compute a kill probability for each case considered;

(d) Compute an average kill probability by appropriately weighing and averaging the results obtained in each case;

(e) Repeat steps (b), (c), and (d) for each of the other candidate systems.

In this manner, the measure of mission effectiveness for each candidate system would be determined.

The computer simulation in this example provides important by-products. If several sets of tactics were employed in conjuntion with the systems to be evaluated, the results of the simulation would automatically suggest the tactics most appropriate for use with each system.

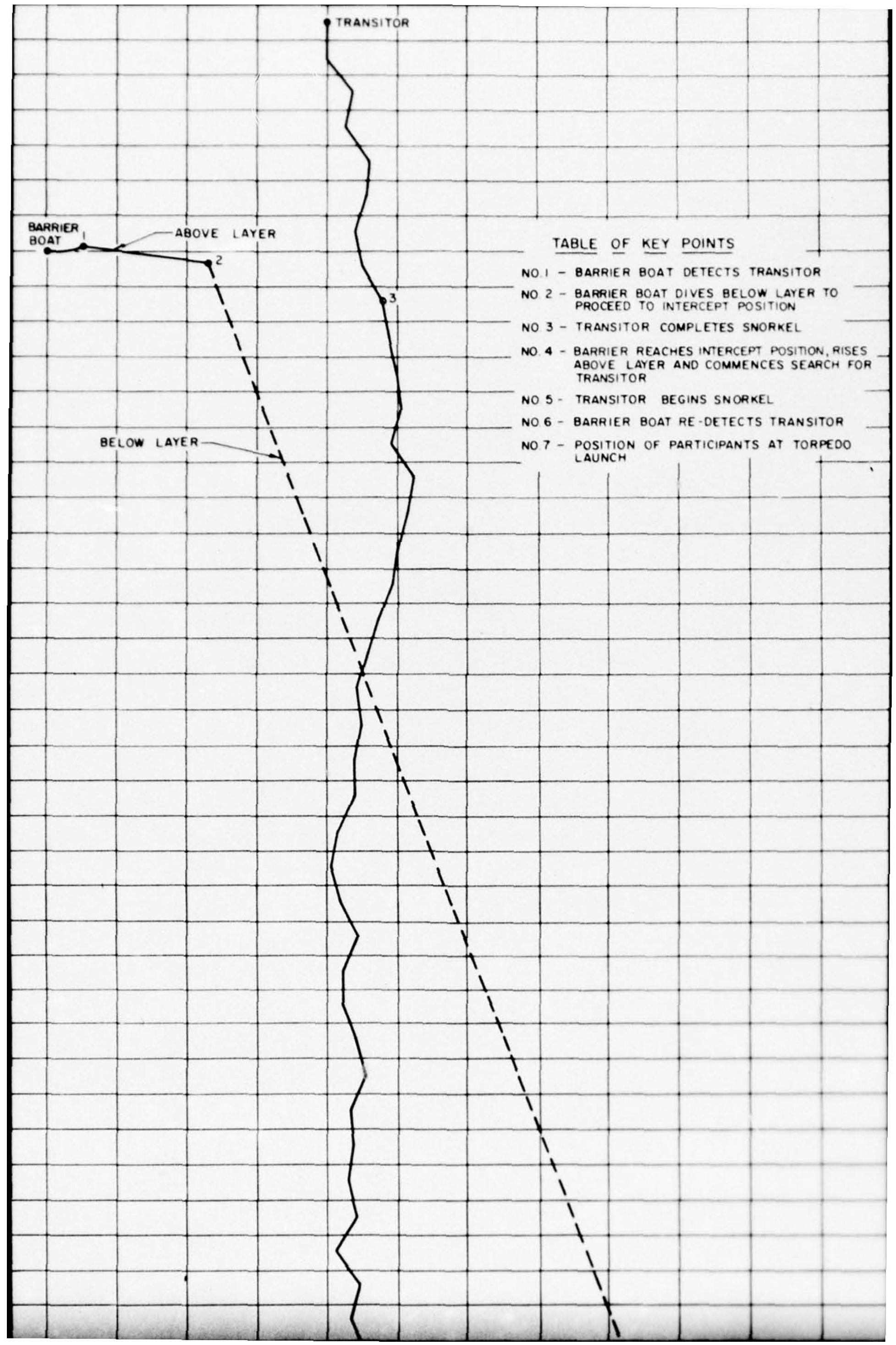
A second important by-product would be contained in the display of the status of the simulation during the course of the engagement. This status display would permit the evaluation of the worth of each component subsystem of the total system during all stages of an engagement. This information should be of significant value in trade-off studies of various components of the total system.

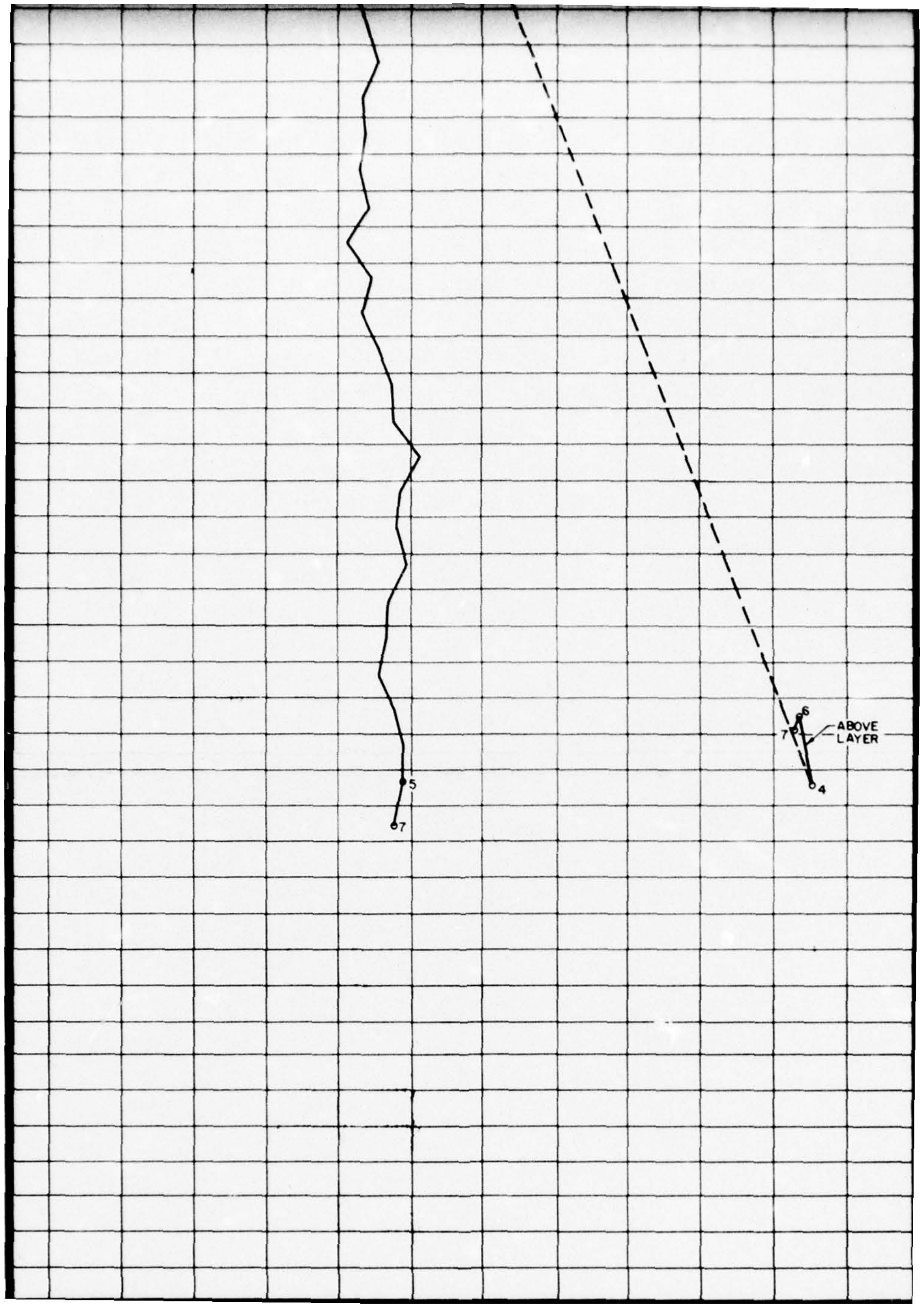
Other types of analyses, such as the evaluation of the variation of performance parameters of existing subsystems or the evaluation of tactics, would be carried out in a manner similar to the example just described.

The results of a single exercise of a combat simulation model are illustrated in Fig. 1. An engagement between a diesel-electric submarine patrolling a barrier and another diesel-electric submarine attempting to transit the barrier is illustrated. The engagement was simulated using the Forward Area Patrol Mission Computer Simulation Model to be described later in this memorandum.

In this example, the patrol submarine possesses a detection advantage. The patrol submarine detects the transitor while the latter is snorkeling and attempts to estimate the transitor's course and speed. Once this course and speed have been estimated, the patrol submarine estimates the position at which the transitor will next snorkel, and proceeds to that point to intercept.

The transitor, however, is following an evasive course. As a result, the patrol submarine computes an intercept position which is some distance from the transitor's base course. Nevertheless, the patrol submarine re-detects the transitor when he snorkels, and launches a weapon. At the point of weapon launch, the kill probability is computed without displaying continuing positions of the boats.


TRANSITOR
BARRIER BOAT
ABOVE LAYER
BELOW LAYER
1
2
3
TABLE OF KEY POINTS
NO. 1 - BARRIER BOAT DETECTS TRANSITOR
NO. 2 - BARRIER BOAT DIVES BELOW LAYER TO PROCEED TO INTERCEPT POSITION
NO. 3 - TRANSITOR COMPLETES SNORKEL
NO. 4 - BARRIER REACHES INTERCEPT POSITION, RISES ABOVE LAYER AND COMMENCES SEARCH FOR TRANSITOR
NO. 5 - TRANSITOR BEGINS SNORKEL
NO. 6 - BARRIER BOAT RE-DETECTS TRANSITOR
NO. 7 - POSITION OF PARTICIPANTS AT TORPEDO LAUNCH



ABOVE
LAYER
6
7
4
5
7

3. A GENERAL ANTI-SUBMARINE WARFARE COMBAT SIMULATION MODEL

For the purposes of this Technical Memorandum, the term "digital computer simulation" is defined to be a digital model of a real world situation, incremented through a simulated time environment. The central and most difficult tasks in simulation are the definition of the problem and the reduction of the real world situation into a meaningful and useful set of abstractions. In the following section, the problem of combat simulation will be explicitly defined. The remainder of the chapter will be devoted to reduction of the problem to a set of abstractions which may be used to adequately simulate ASW combat with a digital computer.

3.1 PROBLEM DEFINITION

The general problem of simulating combat is to simulate the course of an engagement from initial encounter to ultimate conclusion for the arbitrary confrontation of an arbitrary number of participants each of whom may possess:

1. Certain specified information sensing devices,
2. Certain specified information processing devices,
3. Certain communication devices,
4. Certain specified weapons,
5. A specified amount of previously acquired information.
6. A specified tactical doctrine,
7. The ability to assess information available to him and to make decisions based upon his assessment, and
8. The ability to control his own or his vehicle's motion, his own subsystems and his own weapons.

In addition, the simulation model is required to be sufficiently general so that different systems, different tactics, different environmental conditions, and different situations can be incorporated without undue difficulty.

3.2 BASIC CONSIDERATIONS IN ASW COMBAT SIMULATION

Combat is, in reality, a very complex interaction among participants each of whom possesses certain combinations of the capabilities listed in the problem definition. To simulate any complex process occurring in the real world, it is first necessary to identify each essential component of the process. Once this has been done, the simulation of the process consists of the simulation of the behavior of, and the interaction between, each essential component during the course of time.

In the most general terms, the essential components of combat are:

1. The command and control function of each participant,
2. The relevant machines involved in the combat, and
3. The medium (environment) in which the combat occurs.

The command and control function consists of the processes of assessment and decision making and the act of implementing these decisions. Capabilities 5 through 8 of each participant as specified in the problem definition are the basic elements of the command and control function. The relevant machines involved in the combat are the various participating vehicles, information sensors, processors, and communications subsystems and weapons. It should be noted that upon launch certain weapons, such as homing torpedoes, should be regarded as participants in the combat. Capabilities 1 through 4 as specified in the problem definition involve

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the relevant machines. The medium is an essential component of combat because it affects both the performance of machines and the command and control function.

Each component of combat interacts with every other component, either directly or indirectly. Examples of direct interactions are (1) the radiation of information by certain machines (such as ships), the flow of this information through the medium, and the reception of this information by other machines (such as sonar sensors), (2) information flow from sensing and processing machines to command and control functions, and command and control's direction of certain machines such as own ship motion. The interaction between two command and control functions is an example of an indirect interaction. The alteration of one participant's course of action by his command and control function may alter the second participant's assessment of the situation. This new assessment could require a different course of action on the part of the second participant. All of these interactions will be discussed in detail later.

The type of combat considered places more or less obvious restrictions upon the locale, the participants and their capabilities. Thus, ASW combat must occur in some region of the ocean. The simulation must be capable, however, of treating arbitrary oceanographic conditions and arbitrary geometries of encounter.

The participants in ASW combat as considered in the model being discussed here are restricted to the following:

1. Submarines,
2. Surface Vessels,
3. Airplanes and Helicopters,
4. Certain Detached Sonars,

5. Certain Countermeasure Devices,

6. Certain Weapons.

The information sensors and processors are limited to:

1. Communication Equipment,

2. Optical Equipment,

3. Acoustic Devices,

4. Electro-Magnetic Devices,

5. Fire Control and Tracking Information Processors.

The participant's weapons are restricted to the following:

1. Hedgehog,

2. SUBROC,

3. ASROC,

4. Torpedoes,

5. Mines,

6. Aerial Bombs,

7. Artillery.

3.3 THE ROLE OF STATISTICS IN ASW COMBAT SIMULATION

Before discussing in detail the construction of a general ASW combat simulation model, the role played by statistics in such a model will be considered. The description of the effects of the medium and the performance of certain machines is in part statistical in nature. For example, the propagation loss in the ocean from a fixed source to a fixed receiver with stationary oceanographic conditions is found to vary about some fixed value. The variation in propagation loss is apparently due to variation in the microstructure of the

ocean. Range information provided by ranging subsystems is found to vary about some value even when all known relevant parameters are constant. The performance of detection subsystems is generally expressed in terms of detection probability.

The accurate simulation of all of these processes must include the proper statistical description. The effects of these statistics must be accounted for in the evaluation of the results produced by the model. A method of doing this would be to average out the statistics by repeatedly exercising the model.

Tactics, however, should not be treated on a statistical basis in the model. The command and control function for each participant should consist of a specified plan of action for all contingencies. To be useful, the simulation of each command and control function must be amenable to convenient alteration so that logical tactical alternatives can be considered. Only a non-statistical treatment will enable the tactics to be studied in the detail required by analyses addressed in this memorandum.

3.4 BASIC ORGANIZATION OF THE COMBAT SIMULATION MODEL

Proper organization of the computer simulation is required to accurately treat the interactions between the various essential components of the combat. This organization will be discussed in this subsection, and a detailed discussion of the individual components will comprise the remainder of the chapter.

Figure 2 is a schematic representation of most of the direct interactions between the essential components of combat. The only interaction not shown is a collision or near collision of participants. The figure depicts one command

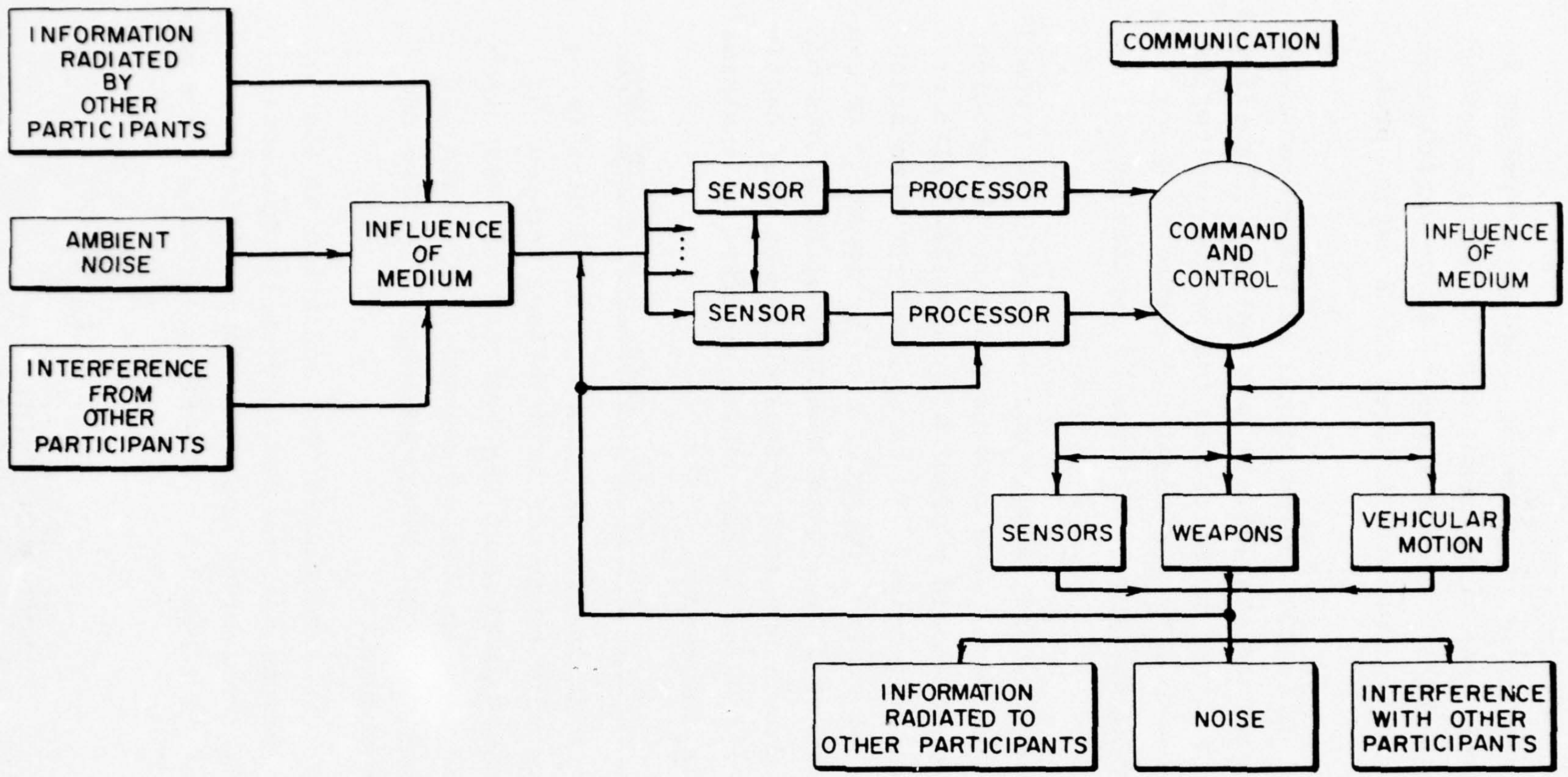

FIG. 2 – DIRECT INTERACTION OF MAJOR COMPONENTS IN ASW COMBAT SIMULATION

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and control function, the components providing information to it, the components controlled by it, the interaction of all these components, and the influence of the actions of the command and control function upon the sensors possessed by the other command and control functions involved in the combat.

The Command and Control functions are the central components of combat. Just as the decision makers drive the actual combat, so should the simulation of their actions drive the computer simulation. If a computer program is to accurately simulate combat, it must be organized around the command and control function of each participant.

The command and control function may be thought of as continuous repetition of the following steps:

1. Assessment,
2. Decision, and
3. Action.

The first step is the assessment of the situation. The second step is the decision to act in accordance both with the assessment of the situation and with own objectives. The third step is the action to implement the decision.

Figure 3 is a schematic representation of the cyclic repetition of the command and control process and its interaction with the subsystems and vehicles. The dashed lines in Fig. 3 represent information flow between participants. The lines are dashed to indicate that one participant may or may not be aware of the other participant's actions.

The concept that combat is the orderly repetition by each participant of certain steps, as illustrated in Figure 3, is to some extent an idealization. Combat is in fact the interaction of a number of time-dependent processes, occurring simultaneously. Nevertheless, the concept of combat as illustrated can serve as a basis for the organization of a digital computer simulation, provided that the interaction between the various time dependent processes is properly accounted for.

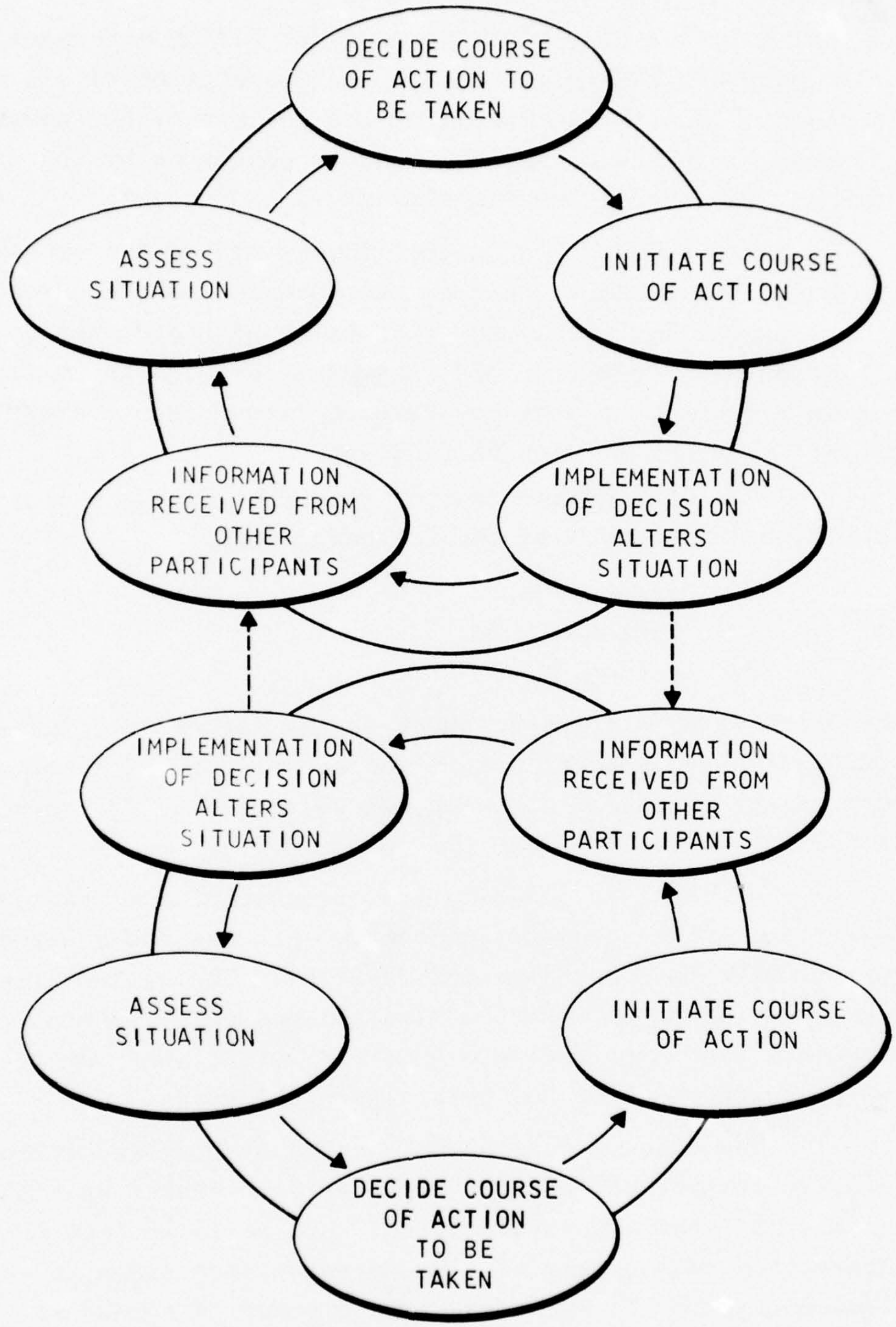

FIG. 3 - CYCLIC REPRESENTATION OF COMMAND AND CONTROL FUNCTION IN COMBAT.

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The time-dependent processes in combat are:

1. Vehicular Motion,
2. Information Flow,
3. Subsystem and Weapon Performance,
4. Variations of the Medium,
5. The Assessment Process,
6. The Decision Making Process, and
7. The Action Steps.

All of these processes proceed simultaneously, and each process influences one or more of the others. Proper treatment of the simulation of the flow of time and proper organization of the computer program are required to adequately account for the coupling between processes.

In digital computer simulation, the continuous passage of time must be represented by finite time steps. The validity of the use of finite time increments to simulate continuous or discrete, coupled processes is well known, and will be only briefly discussed here.

The finite time increment technique proceeds as follows: At the end of each time increment the changes in status of all time-dependent factors occurring during that time increment are evaluated. All coupling between the various time-dependent factors can be considered, provided that the character of the coupling is known. It is only necessary to organize the flow of the computer program in such a way that the time-dependent factors and couplings are computed in the proper order. Figure 4 shows the basic program flow for combat simulation.

The "Action Steps" require special consideration. An Action Step that alters the course of action of any participant can alter the time dependence of all other time-dependent processes.

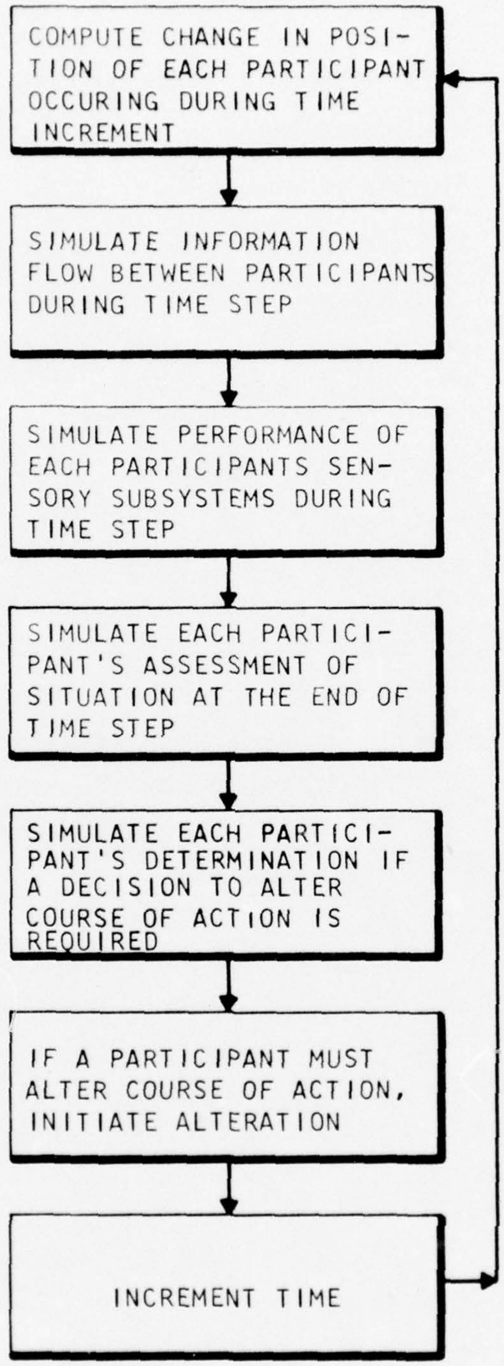

FIG. 4 - BASIC PROGRAM FLOW FOR COMBAT SIMULATION

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The time of occurrence of an Action Step cannot be predicted from initial conditions. Thus, the Action Steps couple all of the time-dependent factors in an a priori unpredictable way.

If the finite time increment technique is used in the simulation, an Action Step can only occur at the end of each time increment. Therefore, the selection of a proper time increment must be governed by accuracy considerations of the individual time-dependent factors and, in addition, the magnitude of the time increment must be selected so that the results of the simulation will not be materially affected should the decision point have occurred at any time during the time step.

3.5 THE COMMAND AND CONTROL FUNCTION

Figure 5 is a schematic representation of the Command and Control Function for each participant and its interfaces with the subsystems and vehicles which it controls. One of the factors contributing to the assessment step of Command and Control, the Information Bank, has been subdivided in some detail because each of the indicated subdivisions represents an important aspect of the computer simulation.

The first step in the Command and Control Function is the Assessment Process. As indicated in Fig. 5, three factors enter into an assessment. The first factor is the "Information Bank". The Information Bank is the cumulative total of all information received from all participants in the combat. It is processed information. It may be either processed and displayed by the subsystems themselves, or it may be processed by personnel subordinate to Command and Control. Two inputs are shown to the Information Bank, "Information Sensors and Processors" and "Information From Other Sources". As all information received from external sources is received via sensors, the indicated division is for simulation purposes. The Information Sensors and Processors division is information received via subsystems

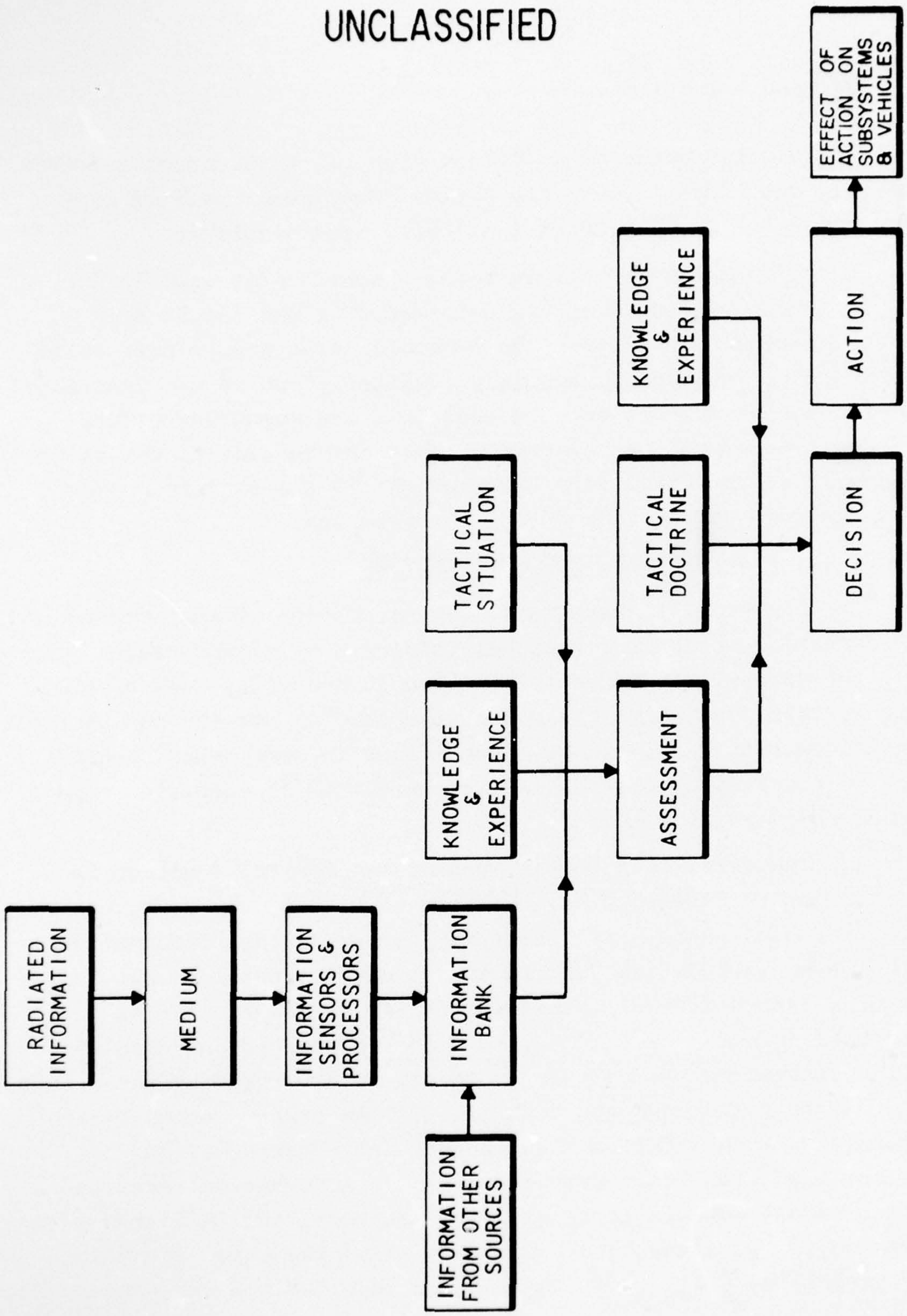

FIG. 5 COMMAND AND CONTROL FUNCTION AND ITS INTERFACES

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whose performance is to be simulated in the computer simulation (for example, information received via sonar). The "Information From Other Sources" division is information received via subsystems whose performance normally is not to be simulated (for example, radio messages). The simulation of the subsystems providing information to the information bank will be the subject of a later section of this chapter.

The second element entering into the Assessment Process is "Knowledge and Experience". This is information, either correct or erroneous, possessed by the decision maker, but not derived from the other participants. For example, the decision maker in a submarine will have some idea of the existing oceanographic conditions and of the detection range of his detection subsystems as a function of these oceanographic conditions. Thus, at the time a detection is achieved, his assessment would necessarily be dependent upon his estimated maximum detection range.

The third factor entering into the Assessment Process is the "Tactical Situation". The decision maker's assessment is based not only on the information available to him, but also upon what he is and has been trying to accomplish. For example, a submarine's loss of contact of a surface vessel might be interpreted differently by the decision maker in the submarine if he were trying to evade the surface ship or if he were attempting to close with the surface ship and launch a weapon.

The result of the assessment process may be thought of as the decision maker's total current evaluation of the situation. This result is one of the three factors entering into the decision process. The second factor entering into this process is the "Tactical Doctrine". This is the mission of the participant, the guide lines by which he should effect this mission and the constraints under which he should operate.

The third factor entering into the decision process is the "Knowledge and Experience" of the decision maker. This controls the implementation of Tactical Doctrine in accordance with the decision maker's assessment of the situation. It might also include reasonable predictions of future action by the other participants.

The objective of the decision process is the determination of that course of action most favorable to success of the decision maker's mission. The action step in Fig. 5 denotes the act of implementing this course of action once determined. Since a possible result of the decision process is to continue on present course of action, the action step may consist of doing nothing to alter the present course of action.

There are only five broad classes of action available to the decision maker in combat. They are:

1. Change own ship's velocity,
2. Change own ship's activity,
3. Alter an Information Channel,
4. Fire a weapon,
5. Create a new participant (e.g. launch a torpedo, activitate a countermeasure device).

Ship's velocity is used here in the mathematical sense and includes such things as changes in course, speed and rate of descent. A change in own ship's activity is any change that alters the information received or radiated by that participant. The commencement of snorkeling by a submarine is an example. The last three classes of action include all controls that a decision maker has upon his own weapons and subsystems.

The action step of each decision maker affects some vehicles and subsystems directly and others indirectly. The effects of the action step will be discussed more fully in the next chapter.

It is probably impossible to simulate the general command and control function because of the enormous variety of situations in which a decision maker might find himself. It is possible to simulate this function for any given type of engagement; the method of achieving this will now be described. It will be clear that many portions of the simulation for one type of engagement will apply to other types of engagements.

The key to the simulation of command and control is the tactical situation of each participant. A participant's tactical situation is his immediate goal and his method of accomplishing the goal. Examples of tactical situations are: patrol according to a preassigned patrol pattern, close with a contact in order to gather information about it, close with a contact on a lead intercept course, evade a contact by diving to maximum depth and running away from the contact at maximum speed. It should be emphasized that a tactical situation applies to each participant and not to the engagement as a whole.

It is necessary to consider each tactical situation in which each participant may find himself. It is also necessary to ascertain all information that the decision maker may possess exclusive of that provided by his information bank. (It is assumed at this point that each participant's information bank has been simulated.)

For each tactical situation, the following must be determined:

1. The participant's course of action;
2. The alteration in this course of action that may be required while in this tactical situation, and the information apprising the decision maker that he should take this course of action;
3. The tactical situations which may logically follow;
4. The information notifying the decision maker to go to another tactical situation;
5. The order of precedence of the tactical situations that may follow. (This is required in case available information suggests to the decision maker that he should go to two or more tactical situations).

Once the tactical situations have been organized as described, it is a straightforward matter to write the computer program to simulate the command and control function. An approach to this simulation will now be submitted.

After each participant's information bank has been updated at the end of a time step, the program branches to the current tactical situation of participant number one. The program checks the information available to that participant, both from the information bank and from knowledge and experience, against the information required to inform that decision maker to go to another tactical situation. This check is done in order of precedence of possible tactical situations. Should the information available indicate that the decision maker should go to another tactical situation, the necessary action to effect this transfer is simulated, and a tag is set so that the program will branch to the new tactical situation at the end of the next time step.

Should the information available to the decision maker indicate that he should not go to another tactical situation, the information is reexamined to determine if a modification of course of action is required while in this same tactical situation. If a modification is required the appropriate action to accomplish this is simulated.

The above procedures are repeated for each participant in the engagement at the end of each time increment.

It should be possible to simulate the command and control function quite adequately, provided guidance from those experienced in actual ASW operations can be obtained.

3.6 MACHINES AND THE MEDIUM

The performance of the machines of combat and the characteristics of the medium in which the combat occurs are intimately related. Hence, it is convenient to combine the discussion of these two essential components. It is also convenient to subdivide the machines into two groups and discuss each group separately. The first subdivision consists of those machines that directly interface with the assessment process of command and control and the second consists of those which directly interface with the action step of command and control.

Before discussing these machines, the relation between subsystem performance prediction and the ASW Combat Simulation Model should be set forth. It is not the function of the combat simulation to predict performance of subsystems. Rather, a major purpose of the combat simulation is to assess the influence of subsystem performance upon the mission effectiveness of the vehicles upon which the subsystems are installed. The combat simulation requires that the performance of each subsystem be specified as a function, if appropriate, of:

1. Performance Variables,
2. Dynamic Variables,
3. Environmental Variables, and
4. Time.

The performance, dynamic, and environmental variables are themselves time-dependent. Thus, the combat simulation is required to treat these variables as a function of time. There is no intent to minimize the importance of subsystem performance analysis. Indeed, the realism of the simulation model rests more upon the adequacy of subsystem performance simulation than upon any other factor. The purpose here is to point out that subsystem performance analysis and combat simulation are separate problems. It is anticipated that the analysis of relevant ASW subsystems will proceed in parallel with the development of the combat simulation model.

3.6.1 Machines That Interface With the Assessment Process

The machines that interface with the assessment process of command and control are the information sensors and processors. These sensors and processors are most logically discussed in terms of information channels. An information channel consists of information sources, noise sources, the medium through which the information and noise is transmitted to a sensor, the sensor, the processor, possibly additional information required by the processor, and the presentation of the processed information to command and control. The performance of human operators or observers is considered to be part of the performance of the processor. A typical information channel is illustrated in Fig. 6.

Each information channel can be characterized by the particular sensor used for reception of the information from the medium and by the processor which processes this information. Information sensors include communication equipment,

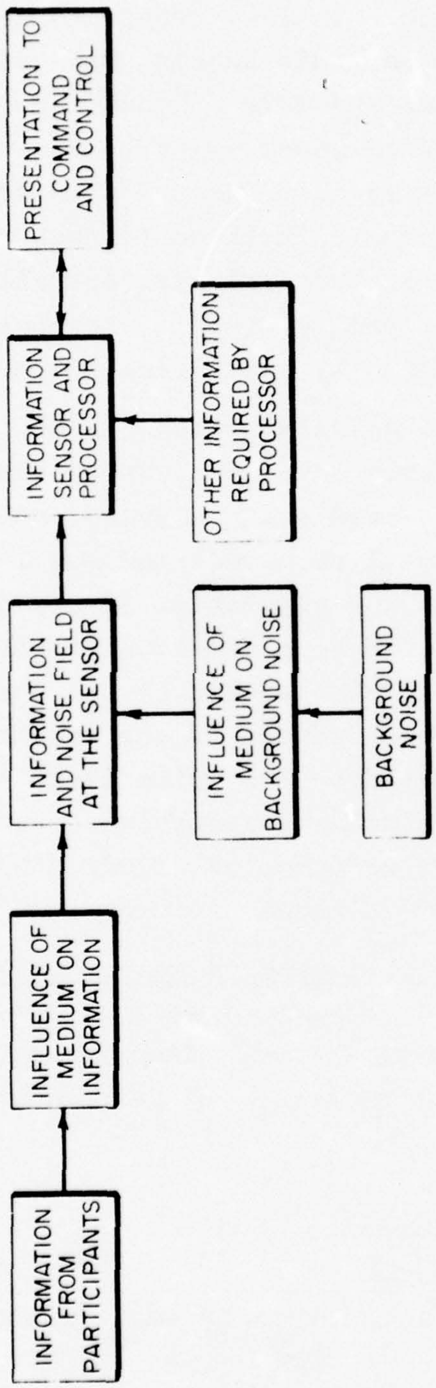

FIG. 6 – INFORMATION FLOW IN AN INFORMATION CHANNEL

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radar equipment, optical sensing equipment (pelorus, periscope, etc.), sonar equipment, etc. In ASW combat, the primary sensors are the sonar devices. Thus, this section will discuss principally the sonar information channels. Should it be necessary to simulate other information channels, they can be included in the simulation, with no significant modification of the computer program organization. It is noted that the effect of another channel can be included without actually simulating the channel. For example, the information received by radio can be included without actually simulating the radio.

The simulation of an information channel can be divided into two parts. This division enables the essential factor to be logically isolated and discussed, and permits the simulation of the channel to be carried out in a general manner. The first part is the simulation of the information and noise field at the sensor as a function of the appropriate dynamic and environmental variables and time. The second part is the simulation of the performance of the sensor and processor as a function of the information and noise field at the sensor, dynamic variables, the performance variables of the sensor and processor, time, and other information required by the processor. The latter division will be discussed first.

3.6.1.1 Sonar information sensors and processors. Sonar information channels can be divided into four basic categories according to the function performed. Each category is composed of both active and passive sonars. The categories are:

1. Detection,
2. Localization,
3. Track Determination, and
4. Classification,

and the specific function performed by each is shown in Table I as follows:

TABLE I. CATEGORIES OF SONAR SYSTEMS

Information Channel Category	Function
Detection	Detection Contact Maintenance
Localization	Contact's Range Determination Contact's Bearing Determination
Track Determination	Contact's Course and Speed Determination
Classification	Contact Classification

A particular sonar can be a part of more than one information channel; for example, a sonar can be a part of a detection information channel and a localization information channel.

The performance to be simulated as a function of time for each category is shown in Table II.

TABLE II. PERFORMANCE TO BE SIMULATED BY INFORMATION CHANNELS

Information Channel Category	Performance to be Simulated
Detection	Probability of Detection Contact Maintenance
Localization	Contact's Range Error Contact's Bearing Error
Track Determination	Contact's Course Error Contact's Speed Error
Classification	Probability of Classification

In the simulation, the exact velocity vector of each participant, the exact range between participants, and the exact bearing of each participant with respect to every other participant are available. Therefore, the simulation of the performance of the localization and tracking information channels is

required to produce only range, bearing, course, and speed errors. These errors are then combined with exact values and the resulting approximate values are presented to command and control.

The performance variables to be considered include such things as:

1. Operating Mode,
2. Integration Time,
3. Processor Threshold,
4. Operator Alert Condition,
5. Pinging Cycles,
6. Spoke Suppression, and
7. Performance degradation resulting from failure or degradation of subsystem components.

The performance of the tracking information channels is a function of own ship motion information in addition to other variables.

To simulate the sonar information sensor and processor portions of the information channels it is necessary to know the performance of each channel as a function of the information and noise field at the sensor, the appropriate performance variables, time and other information as required. Once this is known, a computer program can be constructed which simulates this performance. The performance simulation program must be linked to the appropriate information and noise field simulations (to be described later) and to the command and control function. The link to command and control must be to the assessment both from and to the action step. The link to the action step is required so command and control can select those performance parameters subject to its control.

The knowledge of the performance of the sensors and processors may be obtained from experimental measurements or

from theoretical performance predictions. The exact form of expression of this performance is immaterial, so long as it is amenable to reduction to analytical formulas or numerical tables.

If it is desired to determine the sonar performance required to provide a specified capability to one of the participants, completely hypothetical performance may be inserted in the simulation program.

The simulation of sonar performance must be considered on an individual basis. However, the computer simulation can be constructed so that the simulated performance of one sonar can be replaced by the simulated performance of another sonar in the same category with relative ease. This can be done because all sonars in the same category furnish the same information to command and control. The only modifications necessary are the replacement of one performance simulation by the other, the insertion of the appropriate information and noise field calculations for the new sonar, and possibly certain minor modifications of command and control should the performance variables of the two sonars differ.

3.6.1.2 The information and noise field at the sonar sensor.

The information and background noise received by a sonar sensor are contained in the variations of intensity of the acoustic field in the immediate vicinity of the sensor. In principle, this variation of intensity can be found by constructing the appropriate partial differential equation and then integrating this differential equation subject to appropriate boundary conditions. In practice, this procedure cannot be carried out exactly, but it can be carried out to various degrees of approximation. The precise degree of approximation required by the combat simulation model is dictated by the performance simulation of the sensor and processor of each information channel. The information and noise field at each sensor must be specified in sufficient detail to permit adequate simulation of the processed

information delivered by the information channels associated with that sensor. In the remainder of this subsection, the basic factors which must be considered in the simulation will be listed. In the next subsection a method of simulating the information and noise field to first order will be presented.

To simulate the information and noise fields at sonar sensors in a dynamic computer model, it is necessary to consider:

1. The sources of information,
2. The sources of background noise,
3. The influence of the medium in transmitting the information and noise to the sensor.

Each of these factors must be considered as a function of the dynamic and environmental variables of the combat.

Insofar as passive sonar is concerned, most vehicles in ASW combat serve as information sources in that they radiate acoustical energy into the medium. The intensity of this acoustical energy at unit distance is a function of:

1. The vehicle,
2. The vehicle's speed, and depth,
3. Other noise making activities on board the vehicle,
4. Direction in which the sound is radiated,
5. Time, and
6. Frequency.

The "other noise making activities" factor includes such things as active sonar transmission and acoustic countermeasures as well as other noise making activities aboard the vehicle.

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Insofar as active sonar is concerned, the vehicles in ASW combat may serve as information sources in that they may reflect energy which originates as active sonar pulses. The target reflectivity is referred to as target strength and is a function of:

1. Target vehicle,
2. Pulse length,
3. Frequency,
4. Target aspect,
5. Range,
6. Depth, and
7. Active sonar processor resolution time.

In addition to information, the sonar sensors also receive extraneous signals. These extraneous signals are called sonar background noise. Fig. 7 shows the major sources of sonar background noise.

The first type of background noise concerns only an active sonar signal and is termed reverberation. Reverberation is the transmitted energy which is reflected back to a receiver by the medium and its boundaries. Reverberation is a function of:

1. Source level,
2. Transmit beam pattern,
3. Ping length,
4. Time measured from end of ping,
5. The propagation path,
6. Oceanographic parameters,
7. Scattering cross sections for reverberation, and
8. Frequency.

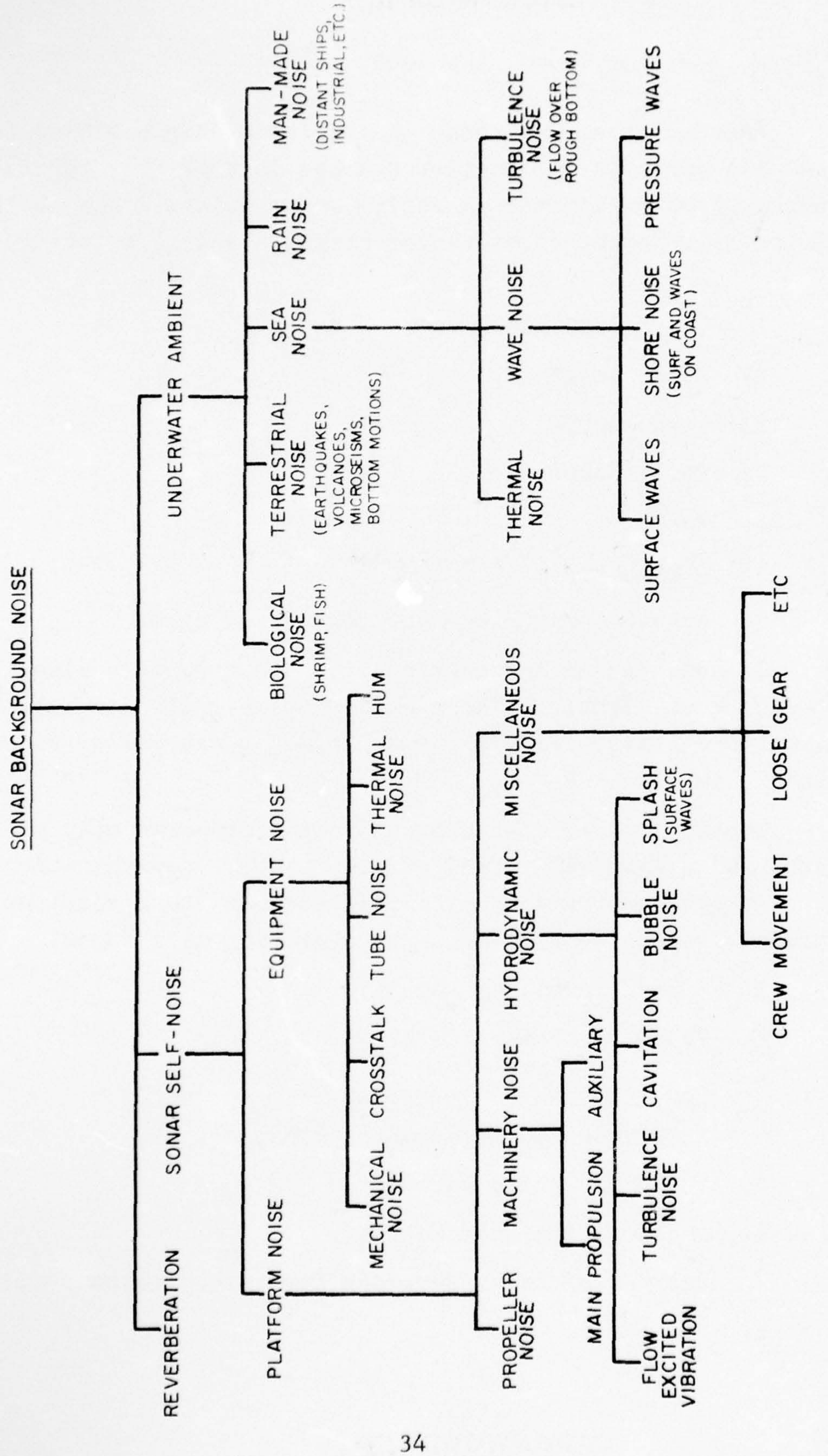

FIG. 7 — ELEMENTS OF SONAR BACKGROUND NOISE

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The second type of extraneous signal is termed underwater ambient noise. The underwater ambient noise consists of the ever present sea noise plus, possibly, noise from other sources such as biological noise, rain noise, and so forth. Thus, the underwater ambient noise is a function of:

1. The source levels of the contributor,
2. The path from contributor to sensor,
3. Oceanographic parameters,
4. Time, and
5. Frequency.

The third type of extraneous information is termed sonar self-noise and consists of platform noise and equipment noise. Sonar self-noise is a function of:

1. The source level of the noise contributor which is in turn a function of the vehicle, vehicle's speed, vehicle's position, and any other noise making activity,
2. The path from contributor to sensor,
3. Time, and
4. Frequency.

The ocean medium exerts an influence on each sonar information channel. The ocean serves as the means by which information and noise is physically propagated to the sensor. The intensities of the information and noise decrease, in general, as they propagate from the source. This decrease in intensity is termed propagation loss, and is the major medium influence which must be accounted for in the combat simulation. It may also be necessary to account for alterations in wave form as the energy propagates. Propagation loss is a function of:

1. The position of the source,
2. The position of the receiver,
3. The paths over which the sound travels,
4. Oceanographic parameters, and
5. Frequency.

Thus, to simulate the information and noise field at each sensor it is necessary to know, as a function of the listed time-dependent parameters, the radiated noise level, the target strength, and, the self-noise level at each participant. In addition a method of calculating the reverberation level for each active sonar, the propagation loss between each pair of participants, and the ambient noise levels must be included. Finally, coupling, if any, between these factors must be included.

As in the case of sonar performance, the knowledge of the factors involved in the information and noise field calculations may be obtained from experimental measurements or theoretical predictions. At present, experimental data is the best source for radiated noise levels, self-noise levels, ambient noise levels, and target strengths. Theoretical calculations are the best source of reverberation and propagation loss due to the lack of experimental data for the wide range of oceanographic parameters necessary to generalize the simulation.

3.6.1.3 <u>A first order approximation to the information and noise field at the sonar sensor</u>. In many cases sonar performance can be expressed in terms of an information and noise field which is specified by the source's range and bearing and the short-time average signal-to-noise level at the output of the sonar beamformer. This representation in effect shifts the information and noise field-sonar interface from the sensor to the output of the beamformer.

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In the model to be described in the next chapter, sonar performance is simulated in terms of short-time average signal-to-noise levels. These signal-to-noise levels are computed utilizing equations (1) and (2), below.

Active Sonar

$$S/N = [S_o - PL - H_T - H_R + TS] - [10 \log (N_A + N_S + R)] \quad (1)$$

where

S_o = the source level on the axis of the main lobe (dB);

PL = the two-way propagation loss (dB);

H_T = transmission pattern losses to account for the target not lying on the axis of the main transmit lobe (dB);

H_R = receiving pattern losses to account for the target not lying on the axis of the main receive lobe (dB);

TS = target strength (dB);

N_A = intensity of ambient noise integrated over the receive beam pattern;

N_S = intensity of self-noise integrated over the receive beam pattern;

R = intensity of reverberation integrated over the receive beam pattern.

Passive Sonar

$$S/N = [S_R - PL - H_R] - [10 \log (N_A + N_S)] \quad (2)$$

where

S_R = the radiated signal of the target integrated over the receiving beam pattern (dB);

PL = the one-way propagation loss (dB);

H_R = receiving pattern losses to account for the target not lying on the axis of the main receive lobe (dB);

N_A = intensity of ambient noise integrated over the receive beam pattern;

N_S = intensity of self-noise integrated over the receive beam pattern;

It should be noted that the above equations are general provided that the indicated separation of effects is valid, and that each term in the equation can require a very sophisticated analysis before it can be evaluated. For example, the evaluation of the propagation loss (PL) term can be obtained in many different ways, ranging from a hand calculation to a complex simulation including all oceanographic factors affecting propagation loss.

3.6.2 Machines That Interface with the Action Step

Each participant in an ASW Combat Simulation has five possible tactical decisions available to him, as has been discussed previously. These decisions concern change of the participant's velocity vector (i.e., change course, change speed), change in the participant's activity (i.e., start or stop snorkeling), weapon launch, and control of information channels. An approach to the simulation of the factors directly affected by this implementation will now be presented.

The motion of each participant in the simulation is described by a differential equation, which can be integrated at each time step to produce the new position and orientation of the participant at that time.

An activity change is anything done by a participant other than change of velocity which alters the nature of the information either received or radiated, or both. For example,

if a submarine starts snorkeling, the radiated noise as well as the self-noise of that participant are markedly increased.

To simulate the change of activity, radiated noise and self-noise information must be provided as a function of the possible activity for each participant.

Each participant in the simulation may have the capability of launching a weapon. The particular types of weapons generally employed in ASW combat are the following:

1. Hedgehog,
2. SUBROC,
3. ASROC,
4. Torpedoes,
5. Aerial bombs,
6. Artillery, and
7. Mines.

Once the weapon has been launched it becomes a participant in the simulation, possibly possessing a command and control function, information sensors, and decision implementation hardware, as well as radiating information to other participants.

The simulation of the performance of these weapons can be divided into three areas once the command to fire the weapon has been given. The initial area of simulation is the launch phase, during which the weapon accelerates or turns to reach a predetermined trajectory. The second area of simulation is the midcourse phase, during which new trajectories may be achieved if necessary (and if the weapon has this capability). The third area is the terminal (homing) phase in which the weapon closes with the target and explodes if triggered.

Information channels may be altered by the decision maker, thus changing the types of information stored in the information bank.

In addition, the opening of an information channel may change the information radiated by the participant to the medium. For example, if a participant uses his active sonar, he radiates a signal which can be received by other participants, thus betraying the presence, and possibly the position, of the first participant. Therefore, the simulation must be provided with radiated noise as a function of the opening or closing of information channels, when applicable.

As was the case with sonar performance, the information necessary to simulate hardware performance in the implementation of decisions is derived from data analysis or from a performance prediction model.

4. THE FORWARD AREA PATROL SIMULATION MODEL

In this chapter, a detailed description of the factors considered in the preparation of a digital computer program to simulate the forward area patrol mission is presented. A programming level description of the computer program is given in the Appendix. This program was prepared to assist in the evaluation of the effectiveness of certain sonar subsystems proposed for the SS/SSN phase of the SISS program. (A program phase to evaluate the effectivenss of certain sonar subsystems proposed for installation on the Post World War II diesel-electric and the pre-SKIPJACK nuclear attack submarines).

4.1 INTRODUCTION

Briefly, the forward area patrol mission involves the encounter between a patrol submarine (sometimes called the Barrier Submarine) assigned to patrol a certain geographic region (the barrier), and a transitor (sometimes called the Penetrator). The mission of the patrol submarine is to kill any submarine which enters his assigned patrol region. The patrol submarine must not leave his assigned patrol region. The mission of the transitor is to traverse the barrier region. The first concern of both submarines is to avoid being killed themselves. The patrol submarine is provided with the subsystems under consideration in the SS/SSN program. The transitor is provided with only detection and bearing determination capability.

Time limitations imposed by the SS/SSN study made it impossible to thoroughly treat every aspect of the problem as discussed in Chapter 3. The simulation, however, addresses all of the salient features of the SS/SSN problem.

For example, the transitor submarine has not been provided with a weapon. The mission of the transitor is to pass through the barrier and hence he would only attack the patrol submarine in rare instances. Also, reverberation has not been

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included in the program. The high sea state specified for the problem, however, implies that active sonar is more likely to be noise limited than reverberation limited.

In addition to the aid in evaluating the effectiveness of the SS/SSN subsystems, this model illustrates almost every portion of the general ASW combat simulation discussed in Chapter 3. Thus, it should be a valuable foundation upon which to construct a more general and more complete ASW combat simulation.

The organization of this chapter conforms to the organization of the computer program, and consists of four main sections:

1. Program Control (CONTOL),
2. Position (POSIT),
3. Subsystems (SUBSYS), and
4. Command and Control (TACTIC).

CONTOL is the input-output portion of the program and also performs various housekeeping functions. POSIT simulates the motion of the submarines and corresponds to the uppermost box in Fig. 4. SUBSYS updates the information provided by each subsystem and corresponds to the second and third boxes of Fig. 4. The TACTIC portion performs all other functions indicated in Fig. 4. Thus, TACTIC simulates those assessment and decision processes indicated schematically in Fig. 5. A discussion of each of these four sections follows.

4.2 CONTROL (CONTOL)

This routine has three major functions, namely,

1. Input of variables and initialization,
2. Control of the simulation,
3. Output of variables and terminal prints.

The detailed input of variables is described in the Appendix. The initialization sets all constants to initial values, and stores input data in the working arrays.

The control section of the simulation is best understood by the following diagram (Fig. 8) of the program flow directed by CONTOL:

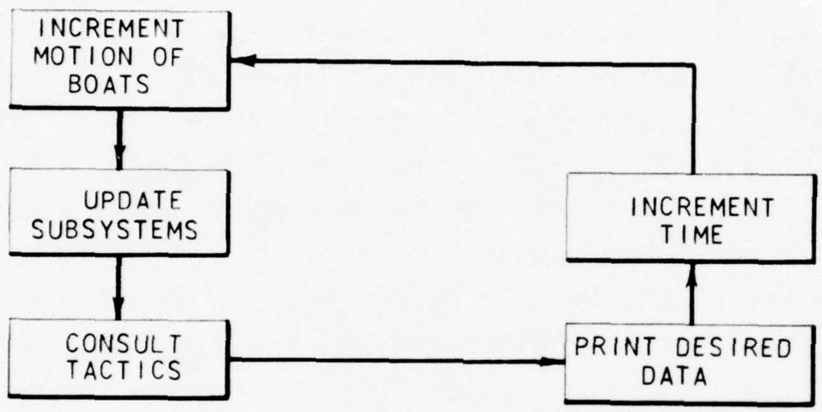

FIG. 8 PROGRAM FLOW DIRECTED BY CONTOL

This flow cycle is continued until the simulation is completed, then the output of variables and terminal prints (as desired) are effected. The various print options and sample output are described under CONTOL in the Appendix (A.1).

It should be noted that once a weapon has been launched, control of the simulation is currently handled by the Choice II B torpedo model. Control is returned to CONTOL by the torpedo model only after a probability of kill has been calculated and the simulation is complete, except for termination prints.

4.3 POSITION (POSIT)

The subroutine POSIT is entered to increment the motion of each submarine in the simulation model, and compute the new positional information for each submarine. Before discussing the

motion options available to the submarines POSIT, it is necessary to discuss the coordinate system in which this motion is described.

4.3.1 Coordinate System

The coordinate system used in the model is an earth-fixed system (Fig. 9). The origin is at any convenient point on the ocean's surface. The Z-axis is directed radially outward from the center of the earth. The Y-axis is in the plane containing the Z-axis and the earth's axis of rotation, is normal to the Z-axis and is directed in a northward direction. The X-axis is such that X, Y, and Z form a right handed coordinate system. The maximum boundary of the current problems considered is small compared to the radius of the earth; thus, effects due to the curvature of the earth are ignored. The X-Y plane is taken to be the horizontal plane and the Y-Z plane is the vertical plane.

It should be noted that in this coordinate system, depths are negative.

4.3.2 Ship Motion

The computer model is capable of simulating three types of ship motion at present. The types of motion are: (1) constant velocity, (2) constant acceleration and (3) circular horizontal motion, constant speed. The equations necessary to simulate these types of motion are:

4.3.2.1 Constant velocity

$$\vec{R}\,(t_{i+1}) = \vec{R}\,(t_i) + \dot{\vec{R}} \cdot [t_{i+1} - t_i]\ , \qquad (3)$$

where

$\vec{R}\,(t_{i+1})$ is the position vector of the ship at time t_{i+1},

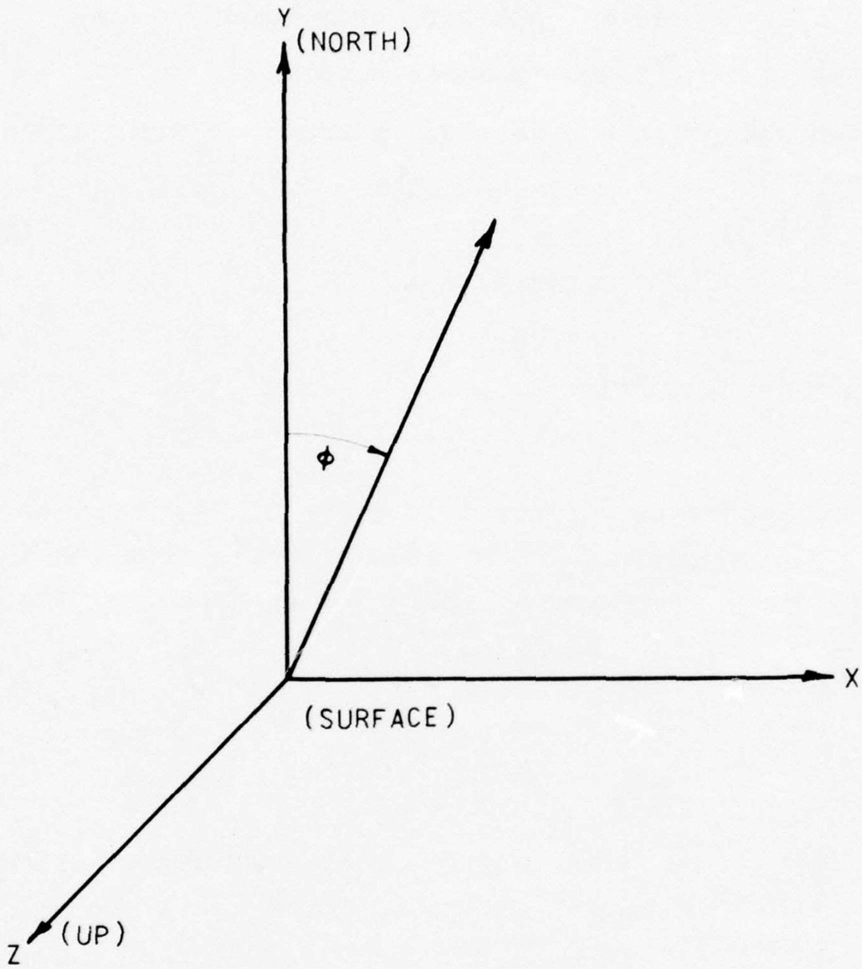

FIG. 9 - COORDINATE SYSTEM

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$\vec{R}(t_i)$ is the position vector of the ship at the previous time point t_i, and

$\dot{\vec{R}}$ is the constant velocity.

The position vectors are expressed in terms of their cartesian components:

$$\vec{R}(t_i) = \begin{pmatrix} X(t_i) \\ Y(t_i) \\ Z(t_i) \end{pmatrix}, \tag{4}$$

$$\vec{R}(t_{i+1}) = \begin{pmatrix} X(t_{i+1}) \\ Y(t_{i+1}) \\ Z(t_{i+1}) \end{pmatrix}. \tag{5}$$

The velocity vector is expressed in terms of its vertical magnitude, horizontal magnitude, and the angle from the Y-axis to the horizontal component of the velocity (see Fig. 10),

$$\dot{\vec{R}} = \begin{pmatrix} C \sin \varphi \\ C \cos \varphi \\ \dot{Z} \end{pmatrix}, \tag{6}$$

where

C is the magnitude of the horizontal component of the velocity,

$\dot{Z}$ is the magnitude of the vertical component of the velocity, and

φ is the ship's heading (see Fig. 10).

4.3.2.2 Constant acceleration

$$\vec{R}(t_{i+1}) = \vec{R}(t_i) + \dot{\vec{R}}(t_i) \cdot [t_{i+1} - t_i] + \tfrac{1}{2} A \,\overset{2}{\cdot}\, [t_{i+1} - t_i]^2 \tag{7}$$

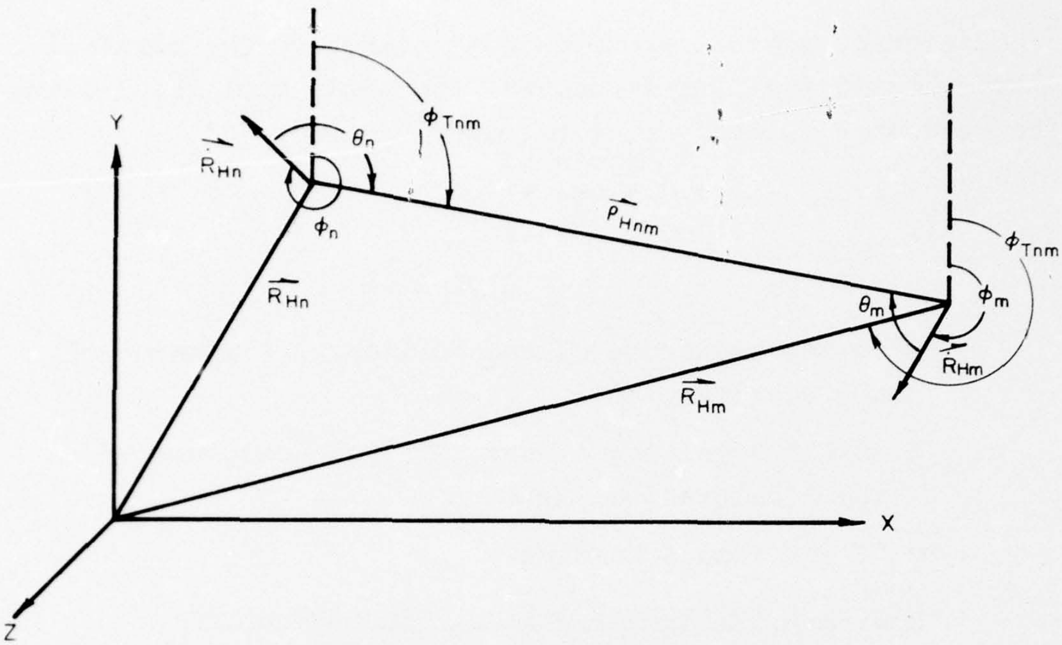

FIG. 10 QUANTITIES ASSOCIATED WITH THE POSITION AND MOTION OF THE SHIPS

$$\dot{\vec{R}}\,(t_{i+1}) = \dot{\vec{R}}\,(t_i) + \vec{A}\cdot[t_{i+1} - t_i]\ , \qquad (8)$$

where

$\vec{R}\,(t_{i+1})$ and $\vec{R}\,(t_i)$ are as defined in the constant velocity case,

$\dot{\vec{R}}\,(t_{i+1})$ is the velocity of the ship at time t_{i+1},

$\dot{\vec{R}}\,(t_i)$ is the velocity of the ship at time t_i, and

$\vec{A}$ is the constant acceleration.

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The acceleration vector is expressed in terms of the vertical magnitude, horizontal magnitude, and the angle from the Y-axis to the horizontal component of the acceleration,

$$A = \begin{pmatrix} a \sin \varphi \\ a \cos \varphi \\ \ddot{Z} \end{pmatrix}, \tag{9}$$

where

a is the magnitude of the horizontal component of the acceleration,

$\ddot{Z}$ is the magnitude of the vertical component of the acceleration, and

φ is the ship's heading.

4.3.2.3 Circular horizontal motion, constant speed

$$\vec{R}\,(t_{i+1}) = \begin{pmatrix} X_c + r_c \cos \frac{C_c}{r_c}(t_{i+1} - t_i) + \psi\,(t_i) \\ Y_c + r_c \sin \frac{C_c}{r_c}(t_{i+1} - t_i) + \psi\,(t_i) \\ Z(t_i) + \dot{Z}\cdot\left[t_{i+1} - t_i\right] \end{pmatrix}, \tag{10}$$

where

X_c, Y_c are the coordinates of the center of the circle of motion,

r_c is the radius of the circle of motion,

C_c is the speed, $C_c<0$ produces clockwise motion, $C_c>$ produces counter clockwise motion,

t_i is the time at some time point of the simulation,

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t_{i+1} is the time at the next time point,

$Z(t_i)$ is the depth at time t_i,

$\dot{Z}$ is the vertical speed,

$$\psi(t_i) = \tan^{-1}\left[\frac{R_y(t_i) - Y_c}{R_x(t_i) - X_c}\right], \text{ and} \qquad (11)$$

$R_x(t_i)$ and $R_y(t_i)$ are the X and Y components of $R(t_i)$ respectively.

The ship's heading at any time point, t_i, is given by

$$\varphi(t_i) = \tan^{-1}\left[\frac{\frac{C_c}{r_c}\left(R_x - X_c\right)}{\frac{C_c}{r_c}\left(Y_c - R_y\right)}\right]. \qquad (12)$$

To insure that $\varphi(t_i)$ is in the correct quadrant, it is necessary to retain the quantity (C_c/r_c) in both the numerator and denominator of the arc tangent argument.

4.3.3 Quantities Associated with Ship's Motion and Position.

Several other quantities associated with ship position and ship motion are required in the simulation. These quantities are illustrated in Figure 10, and the formulas for their computation are:

The Vector from Ship n to Ship m

$$\vec{\rho nm}(t_i) = \vec{Rm}(t_i) - \vec{Rn}(t_i), \qquad (13)$$

where

$\vec{Rm}(t_i)$ and $\vec{Rn}(t_i)$ are the position vectors of ship m and ship n respectively.

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The Horizontal Vector from Ship n to Ship m

$$\vec{\rho}Hnm\ (t_i) = \begin{bmatrix} \rho nm\ (t_i)x \\ \rho nm\ (t_i)y \\ 0 \end{bmatrix}, \tag{14}$$

where

$\rho nm\ (t_i)x$ and $\rho nm\ (t_i)\ y$ are respectively the magnitudes of the X and Y components of $\vec{\rho}nm\ (t_i)$.

The Horizontal Range from Ship n to Ship m

$$|\vec{\rho}Hnm\ (t_i)| = \left[\vec{\rho}Hnm\ (t_i) \cdot \vec{\rho}Hnm\ (t_i)\right]^{\frac{1}{2}}. \tag{15}$$

The True Bearing of Ship m with respect to Ship n

$$\varphi Tnm\ (t_i) = \tan^{-1}\left[\frac{\rho nm\ (t_i)x}{\rho nm\ (t_i)y}\right]. \tag{16}$$

The Relative Bearing of Ship m with Respect to ship n

$$\begin{aligned} \varphi nm\ (t_i) &= \varphi Tnm - \varphi n \quad, \quad \text{if } (\varphi Tnm-\varphi n) \geq 0\ ; \\ &= 2\pi + (\varphi Tnm-\varphi n), \text{ if } (\varphi Tnm-\varphi n) < 0\ ; \end{aligned} \tag{17}$$

where

φn is the heading of ship n.

A detailed discussion of the variables computed by POSIT is contained in the Appendix (A.2). Once all positional data is computed, the subroutine associated with updating the subsystems is entered.

4.4 SUBSYSTEM (SUBSYS)

The simulation model requires an evaluation of the detection, localization, and classification performance associated with the appropriate subsystems. The particular performance parameters required for each subsystem are listed in Table III. Detection performance for the active and passive ranging subsystems has not been determined for this study.

TABLE III PERFORMANCE PARAMETERS REQUIRED FOR EACH SUBSYSTEM

SUBSYSTEMS	REQUIRED PERFORMANCE PARAMETERS
AN/BQR-2B	PROBABILITY OF DETECTION BEARING ERROR
AN/BQR-2( ) DIMUS	PROBABILITY OF DETECTION BEARING ERROR
PUFFS (AN/BQG-4)	RANGE AND BEARING ERROR
AN/BQS-4	RANGE AND BEARING ERROR
AN/BQS-4 MODIFIED	RANGE AND BEARING ERROR
AN/BQH-2C	PROBABILITY OF CLASSIFICATION

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The environmental conditions for which the performance data apply are those stated in SOR 23-29. They are based upon statistical data from the Norwegian Sea, Summer Season, and are as follows:

Summer Season;

Sea State Four;

2000 Fathoms of Water;

Average Bottom Loss of 15 dB.

4.4.1 Passive Detection Performance

Detection performance data in terms of probability of detection in both the convergence zone and the direct path zone are required for the AN/BQR-2B and AN/BQR-2 (DIMUS) subsystems. These data have been generated from a passive performance prediction model in which a certain assumption has been made in the absence of directly applicable data on display-operator performance. The assumption integrates the results of two special purpose experiments to yield a more general model of display-operator performance through which probability of detection can be determined for a specified signal-to-noise ratio and number of target lines on the bearing-time recorder (BTR) display. The validity of the model cannot be determined quantitatively because of the lack of data by which to check the display-operator model. It is thought to result in a reasonable assessment of absolute performance for passive detection systems having a BTR display and to be quite good for determining the relative performance of two or more passive detection systems.

4.4.1.1 The Static performance prediction model. The performance prediction model applies to a static situation in which probability of detection is computed for a fixed target signal-to-noise level and a specified number of target information lines on the BTR. To apply this static model to the dynamic situation

in which target range can change continuously, and in which no meaningful fixed observation time corresponding to a fixed number of lines on the display can be established, a procedure has been adopted through which probability of detection is determined as a function of time. This procedure will be discussed after the static model has been described.

The static prediction model includes two basic steps:

(1) Prediction of the signal and noise levels at the beamformer output for the assumed environmental conditions; and

(2) Prediction of probability of detection for a specified number of target information lines on the BTR at the beamformer output signal-to-noise ratio determined in step (1). A block diagram of the process is shown in Fig. 11.

The prediction of all signal-to-noise levels (step 1) in this program is handled by a separate routine termed STON. As this routine serves localization and classification as well as detection subsystems, it will be described at the end of the subsystem descriptions.

Step (2) accounts for subsystem performance from Point A to Point C. Point B is of interest in the subsequent discussion of step (2).

The performance of each of the passive subsystems can be presented as a set of probability of detection curves, one set for each of the passive detection subsystems. The sets of curves which have been generated for the AN/BQR-2B and AN/BQR-2 (DIMUS) subsystems are presented in Figures 12 and 13 respectively. Once the signal-to-noise ratio of the input to the signal processor has been determined, and the number of lines on the BTR at this signal-to-noise ratio has been specified, then the probability of detection can be obtained directly from the set of curves.

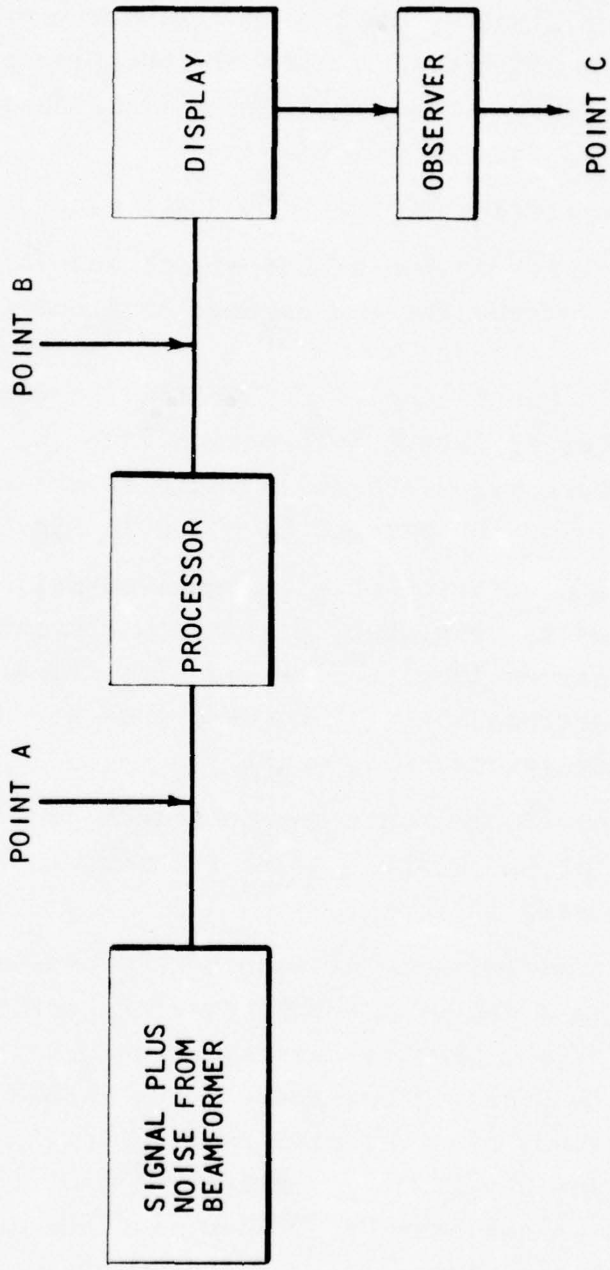

FIG. 11 - BLOCK DIAGRAM OF DETECTION PERFORMANCE PREDICTION MODEL

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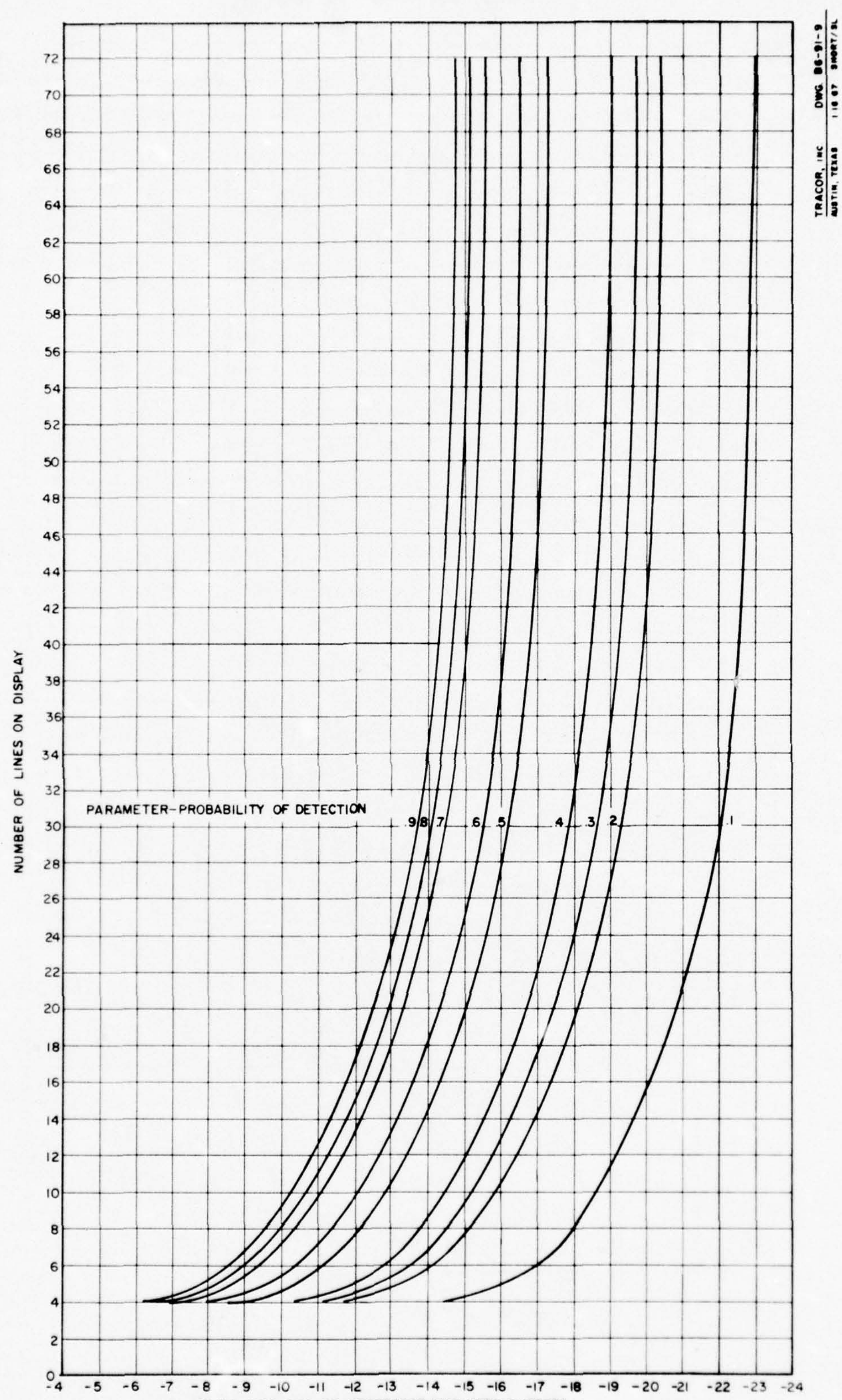

FIG. 12– BQR-2B SONAR DETECTION PERFORMANCE

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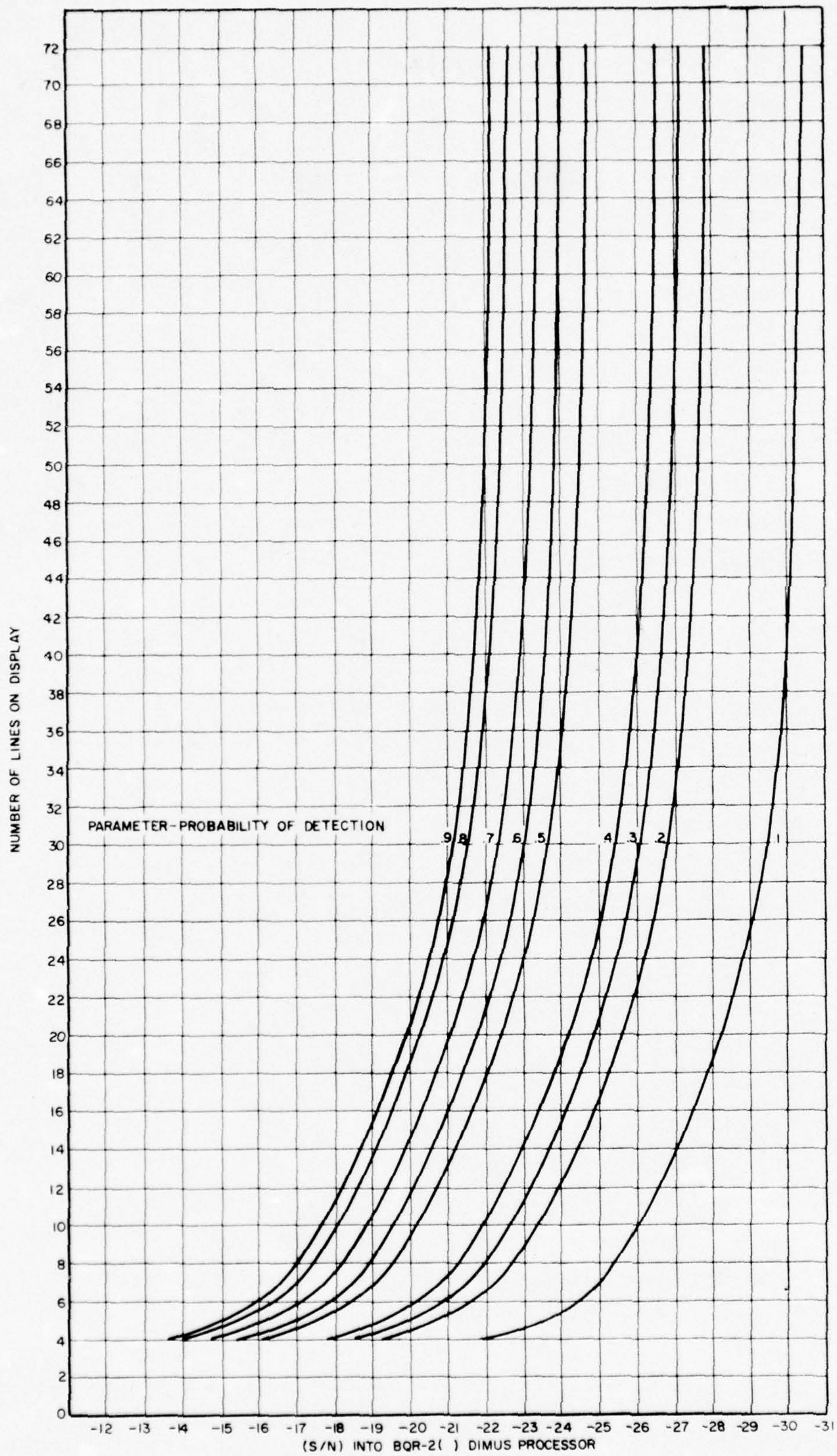

FIG. 13 - BQR-2( ) DIMUS SONAR DETECTION PEFORMANCE

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In order to determine a set of probability of detection curves, the results of two display-operator studies, one by Deatherage* and one reported in TDP S23-19, are used in conjunction with the proper treatment of the signal processor.

Deatherage investigated a 50-line display. He found that for fixed Gaussian signal in Gaussian noise at a particular bearing (1) probability of detection is maximum when the noise marking density is between 0.5 and 0.6, and (2) if the noise marking density is set at 0.5, the probability of detection depends upon the signal-plus-noise marking density according to the curve given in Fig. 14. The study reported in TDP S23-19 resulted in a graph of time to detect the target with 0.5 probability versus required signal-to-noise ratio at the input to the AN/BQR-2B DIMUS signal processor.

In order to utilize the results of these display-operator studies, it is necessary to determine the processing gain of the output signal-plus-noise statistics of the signal processor. A summary of techniques used to determine these signal processor characteristics can be found in P. B. Brown's summary on signal processors+. The procedure carried out consists of two steps:

(1) Determine the processing gain of the signal processor; this is a plot of the processor output signal-to-noise ratio, $(S/N)_B$, plotted as a function of the input signal-to-noise ratio, $(S/N)_A$. $(S/N)_A$ is an average signal power to average noise power ratio. $(S/N)_B$ is the square of $(p - \mu)/\alpha$,

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*Deatherage, B. H., "Summary Report of Results, Conclusions and Recommendations from a Psychophysical Study of the Relative Detectability of Target Tracks in Simulated Passive Sonar Displays", TRACOR Document 63-231-U prepared under Contract NObsr-89265 (Sept.6, 1963).

+P. B. Brown, "A Comparison of the Performance of Several Signal Processors", TRACOR Document 66-203-U, prepared under Contract N123(953) 53354A-NPOLA, (March 1966).

where p is the output signal-plus-noise peak, μ is the noise-only mean at the output, and α is the standard deviation of the noise-only output.

(2) Prepare plots of the signal-plus-noise probability of exceeding threshold as a function of threshold, using output signal-to-noise ratio as a parameter. These curves (one for each signal-to-noise ratio) are then relabeled using the input signal-to-noise ratio, obtained from the processing gain curve determined in step (1), corresponding to specific output signal-to-noise ratios used in preparing the curves. The above procedure has been carried out for the AN/BQR-2B and the AN/BQR-2B DIMUS signal processors.

At this point, it is possible to determine probability of detection for a 50-line display as a function of signal-to-noise ratio into the corresponding signal processor. Using the results of Deatherage's study, it is assumed that the display threshold is set for a 0.5 noise only marking density. Since the probability that the signal out of the processor exceeds a specified threshold (zero in this case) is equivalent to marking density on the display, the curve of Figure 14 can be replotted as probability of detection versus signal-to-noise ratio into the signal processor. This is done by using the signal processor characteristics to determine the $(S/N)_A$ at zero threshold which corresponds to a given signal-plus-noise marking density. The results of following this procedure for both the AN/BQR-2B and the AN/BQR-2B DIMUS signal processors are shown in Figure 15. These curves yield the required information for a 50-line display.

The results of the study presented in TDP S23-19 are used in the prediction of probability of detection for numbers of display lines other than 50. The graph of time to detect with 0.5 probability versus required signal-to-noise ratio into the AN/BQR-2 (DIMUS) signal processor can be replotted to reflect

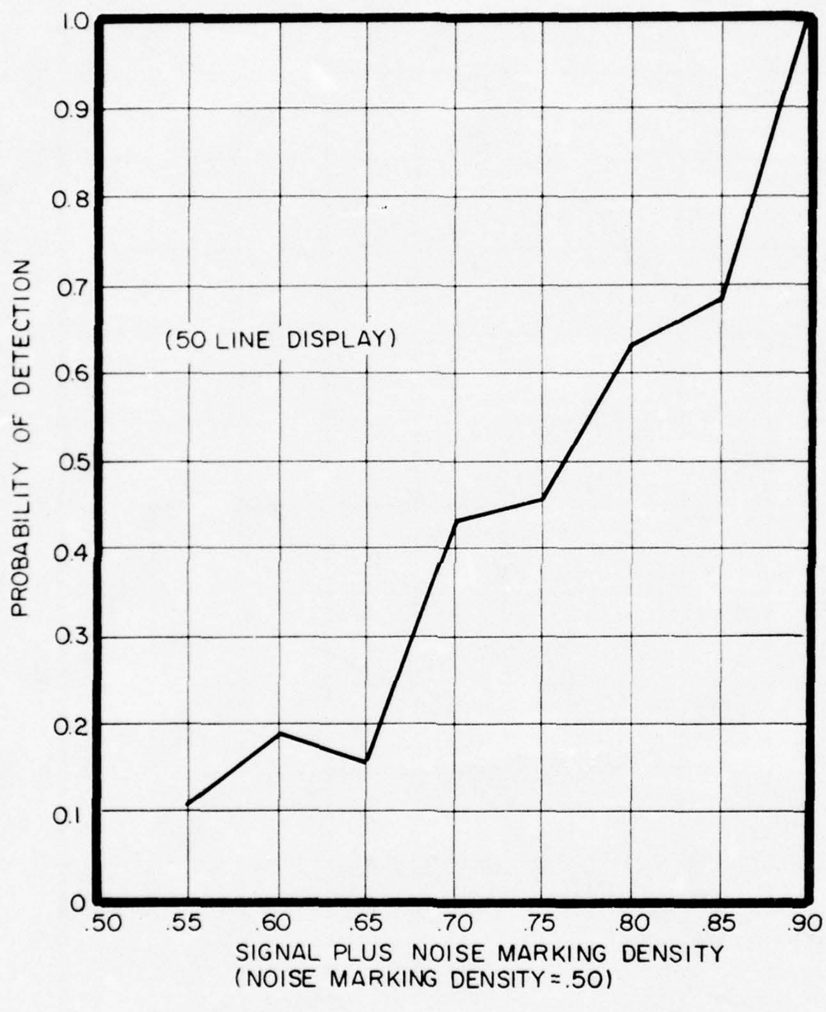

FIG. 14 - PASSIVE DISPLAY - OPERATOR PERFORMANCE

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9/9/67 SHORT/SL

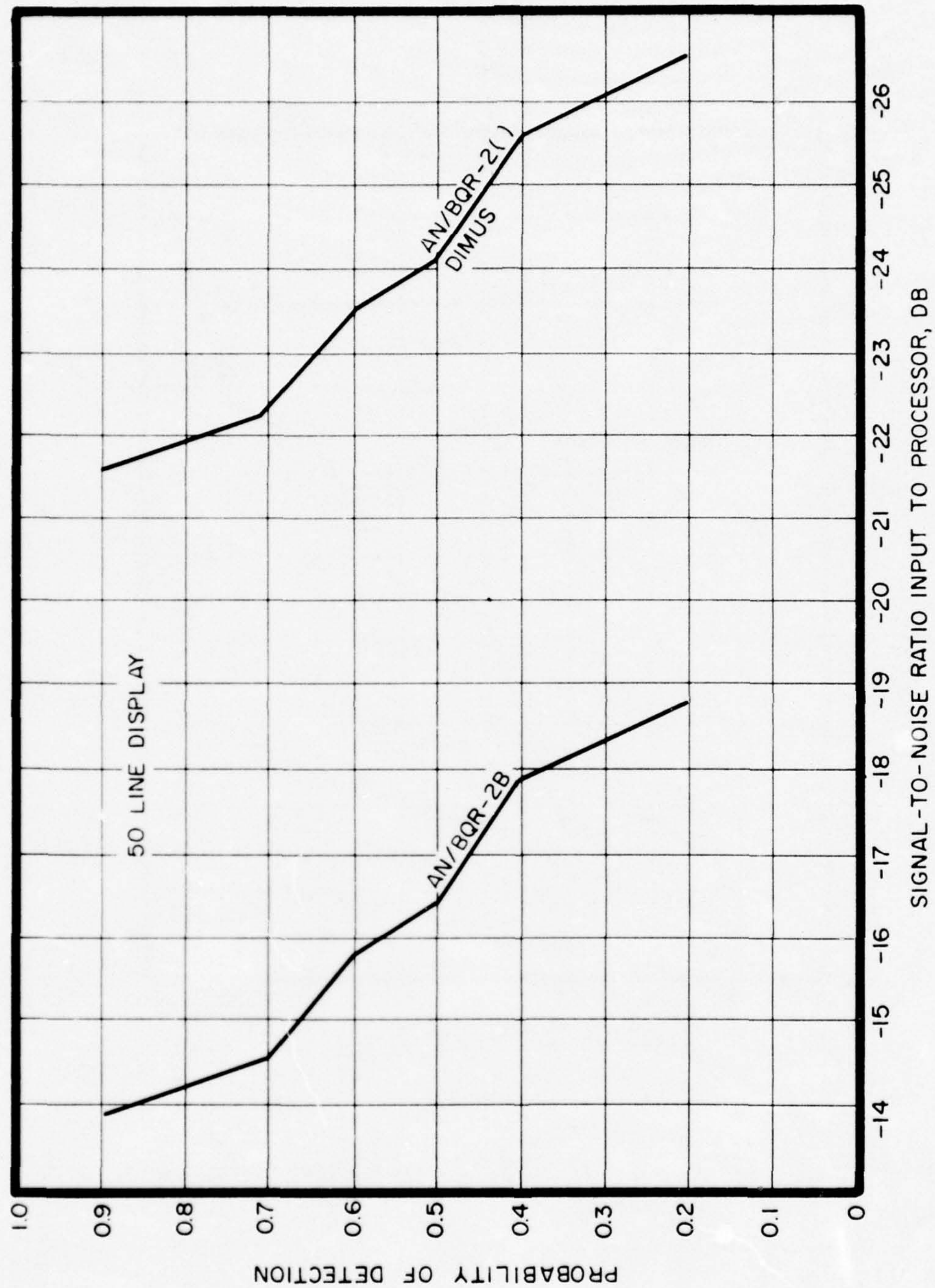

FIG.15 - ADJUSTED PASSIVE DISPLAY-OPERATOR PERFORMANCE

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operator display performance only by properly accounting for the signal processor characteristics. The "time-to-detect" axis can be converted to number of lines on the display, and the "signal-to-noise ratios into the signal processor" axis can be converted to signal-to-noise ratio into the display. This procedure results in the graph shown in Figure 16. Although this graph was measured for 0.5 probability of detection, it is assumed to represent the functional relationship between required signal-to-noise ratio and number of lines on the display for probability of detection between 0.1 and 0.9. The sets of probability of detection curves given in Figures 12 and 13 are established by (1) determining the required input signal-to-noise ratio at 0.1, 0.2, 0.3,...., 0.9 probability of detection from Figure 15; (2) relabeling the signal-to-noise ratio axis of Figure 16 to give signal-to-noise ratio into the signal processor; and (3) shifting the 50-line point on the curve of Figure 15 to coincide with these input signal-to-noise ratios.

4.4.1.2. <u>Procedures for obtaining Detection Performance in the Dynamic Operational Condition</u>. The static performance data discussed in the previous subsection do not supply the performance information required for the combat simulation model. In the model it must be ascertained at all times whether each participant has contact with the other participant.

Furthermore, in the dynamic condition, the signal-to-noise ratio out of the beamformer changes continuously with the target range. This varying signal-to-noise ratio is reflected on the sonar display as a non-uniform signal-plus-noise marking density. To apply the static prediction model to this dynamic condition a procedure has been adopted through which a signal-to-noise field is calculated at each time step of the program. The values in the signal-to-noise field are then tested to yield the greatest probability of detection for that time step.

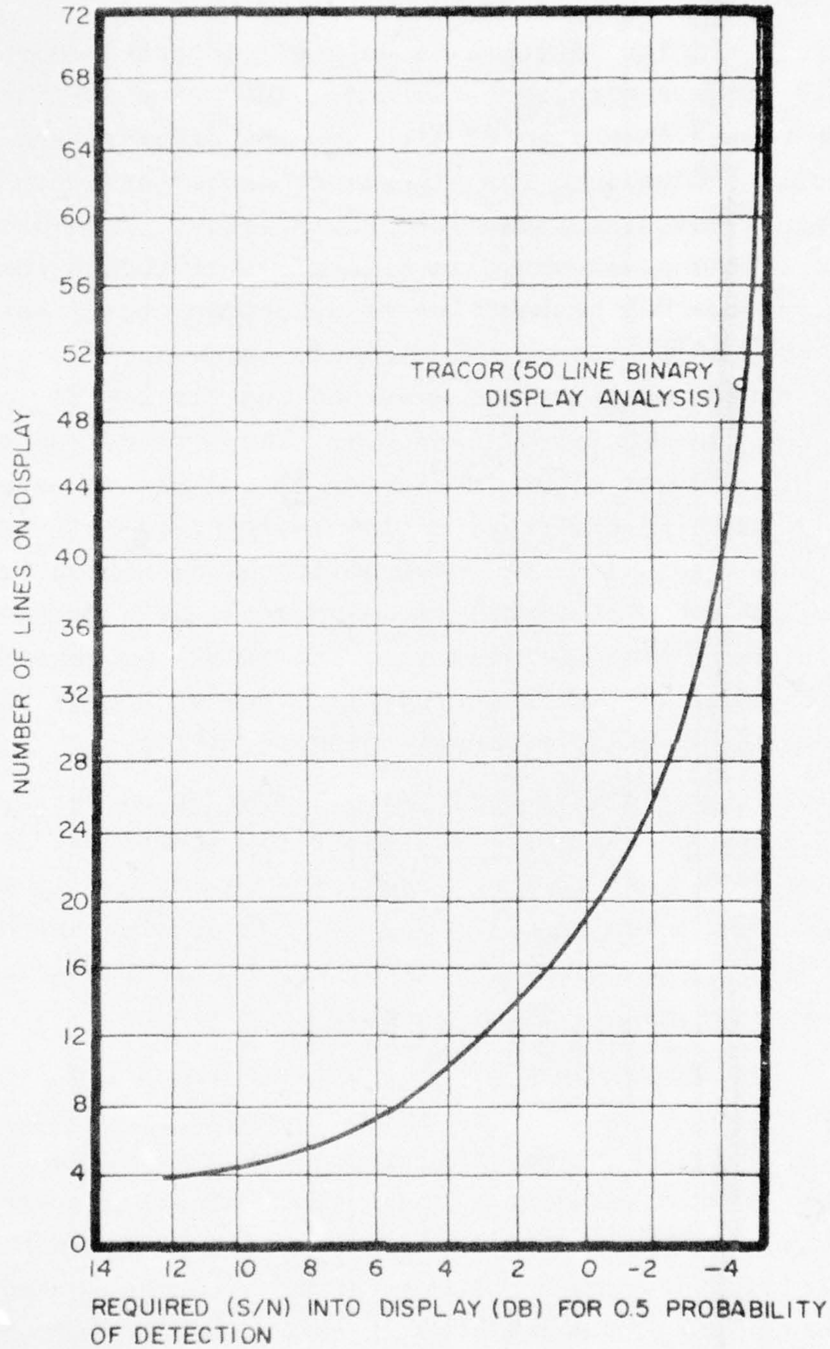

FIG. 16 – BTR DISPLAY – OPERATOR PERFORMANCE

TRACOR DWG. A6-91-7
9/12/67 SHORT/SL

This procedure is based on the assumption that the operator will consider in effect any recent increase in marking density to the exclusion of what occurred before the increase.

This assumption is implemented in the following manner. At each time step, the signal-to-noise ratio at the output of the beamformer is computed for the detection subsystem. If the signal-to-noise ratio is less than a threshold value (the signal-to-noise ratio corresponding to a 0.10 probability of detection for an infinite observation time), a value of $-\infty$ on the log scale is stored in the signal-to-noise table for that time step. This signal-to-noise table represents the display screen seen by the operator. If the table is full, the oldest signal-to-noise ratio is dropped to make room for the most recent data.

Two possible situations must be considered at this point. The first is that the target has been detected, and it must be determined if detection has been lost. The second situation is that the target has not been detected, and it must be determined whether or not detection occurs during this time step. These situations will be discussed separately in the following text.

If the signal-to-noise ratio is below the threshold for five consecutive time steps, detection is assumed lost, the table of signal-to-noise ratios is cleared, and the detection process restarted.

A conditional probability of detection is required to determine if detection has occurred at any particular instant of time. This conditional probability of detection is defined to be the probability of detection at that instant multiplied by the probability of failure to detect prior to the instant in question. Once the conditional probability of detection is determined the question of whether detection has occurred can

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be treated with standard Monte Carlo techniques. In the procedure used here, the conditional probability of detection is not explicitly determined; rather, a Monte Carlo technique is applied to the static detection probability in such a way that the static detection probability is effectively transformed into the conditional probability of detection. The specific procedure is as follows. After a value has been stored in the signal-to-noise table, the values in the table are averaged in the following manner. Let the total number of values in the Table be K, the number of time steps for which information has been displayed to the operator. First, an average signal-to-noise is computed for the K values in the Table. (Recall that K corresponds to the length of time over which the operator observes the target, which is equivalent to some number of lines of information on the BTR display). The average value of the signal-to-noise and the number N are then used to compute the probability of detection from the curves diagrammed in this section. (The computer program actually uses a table look-up and linear interpolation). The averaging process is repeated for the latest (K-1) values in the signal-to-noise table. The probability of detection is again computed from the curves using the new average signal-to-noise and the number (K-1). If the latest probability of detection is greater than that previously computed, it is stored in the probability of detection location. The process is repeated for (K-2), (K-3), . . ., 1, until the maximum value of the probability of detection has been determined. We refer to this maximum value as the static probability of detection at that time step.

The probability of detection is then compared to a detection limit which is initially 0.1. If it is less than this limit, detection is assumed impossible, and no test for detection is made.

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The method used to determine if detection actually occurred at this time step is to select a random number between 0.0 and 2.0. If the number chosen is less than the probability of detection for that time step, detection is said to have occurred. If not, the detection limit is increased by 0.05, to a maximum of 0.50.

The selection of a random number between 0.0 and 2.0 rather than between 0.0 and 1.0 is the process by which the static probability of detection is transformed into conditional probability of detection. The selection of the interval 0.0 to 2.0 was determined by numerical experimentation to be the most appropriate sampling interval based upon physical intuition. The validity of this technique must be established by experimentation.

The increase in the detection limit is instigated in the belief that if an observer cannot detect a target at one time step for a given probability of detection, he will detect nothing in succeeding time steps until the probability increases by some amount (say 0.05). Once the limit reaches 0.50, no further increase in the limit occurs.

4.4.2 Localization Subsystem Performance

Any localization subsystem can be characterized by the following diagram (Fig. 17):

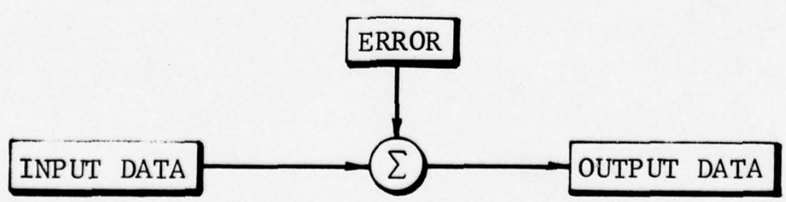

FIG. 17. CHARACTERIZATION OF LOCALIZATION SUBSYSTEM

The input data is the actual range or bearing of the target. The error is approximated as the sum of a bias error and an error randomly selected from a normal distribution of standard deviation σ and mean 0. It is therefore necessary to specify the bias (mean) error and the standard deviation for each localization subsystem, either from a theoretical formula or by a fit to available data.

We distinguish between ranging and bearing systems in the following discussion, rather than distinguishing on the basis of equipment. Hence, PUFFS performs as both a bearing and ranging system. The bearing data has one characteristic error, the ranging data another. PUFFS is therefore treated in the ranging section and in the bearing section of this program.

4.4.2.1 Ranging Systems

PUFFS. According to the MK48 Torpedo Simulation Model CHOICE II-B*, the theoretical range error of the PUFFS subsystem sonar is

$$\sigma_R = \frac{3\sqrt{2}\ (RT)^2}{S_\beta \sin\beta}\,\sigma_B\ , \qquad (18)$$

where

σ_R = range error in yards;
RT = range in yards to target;
S_β = receiver spacing in feet;
β = target bearing in degrees;
σ_B = bearing error in radians, due to noise.

*Greenstone, R., and Tully, J. J., The Effect of Torpedo Radiated Noise on the MK48 MOD 0 Torpedo Weapon System, Part 5, TM 412.2711-67, 6 May 1966, (Contract NOw65-0123-d).

$$\sigma_B = \frac{0.113}{\sqrt{T}\ \ S_\beta \sin_\beta}\left[Q + 0.19\ Q^2\right]^{\frac{1}{2}} \qquad (19)$$

σ_B = error in degrees, due to system noise.

T = integration time;

= $20.6667 + 311111\ Q^*$;

Q^* = Q in dB;

Q = noise-to-signal ratio in power.

An attempt was made to compare the results of this formula with certain measured range errors obtained at Dabob Bay during TECHEVAL and OPEVAL on the AN/BQG-4. The submarine equipped with PUFFS was moving at a very slow speed.

It was first assumed that the noise source was equivalent to a 15 knot ship and that the background noise corresponded to Sea State 2. Using the generalized radiated noise curve, the following errors were computed with the above theoretical formula.

Range	Error
5000 yards	44 yards
8000 yards	450 yards
10,000 yards	1350 yards

If the substituted conditions are assumed to be similar to those existing during the OPEVAL, then the data above can be compared to the data taken on the USS VOLADOR. Between the ranges of 7000 - 9000 yards, the standard deviation of the VOLADOR data, based on 417 samples, was 500 yards. The standard deviation of 32 samples taken at 8000 yards was 471 yards. The subsurface target used in the OPEVAL was the RONQUIL, snorkeling, cavitating, and circling VOLADOR at a range of 5000 yards. Although many unknowns were present, indications were that the PUFFS

equation in the CHOICE II-B model was in reasonable agreement with measured data at ranges out to 8000 yards.

Further study indicated that the theoretical range error was strongly dependent on the value of signal-to-noise ratio. For example, when signal is assumed to correspond to a 3 knot ship, the following errors are calculated.

$$5000 \text{ yards: } \sigma_R = 166 \text{ yards;}$$

$$8000 \text{ yards: } \sigma_R = 1390 \text{ yards;}$$

$$10{,}000 \text{ yards: } \sigma_R = 4180 \text{ yards.}$$

The errors are both large and in considerable disagreement with the experimental results at long ranges. Therefore, since the true experimental value of signal-to-noise was not known in any of the test cases, it must be concluded that an accurate experimental verification of the theoretical formula has not been made.

The standard deviation of all of the experimental data could be fitted rather well by the following formula (outliers removed):

$$\sigma_R = 51.7 + 19.4\,R + 2.68\,R^2 \quad , \qquad (20)$$

where σ_R is in yards, and R is in kiloyards.

This fit indicates verification of the R^2 dependence of the range error which is portrayed in the PUFFS equation. The mean (or bias) error of PUFFS is assumed to be zero.

AN/BQS-4 and AN/BQS-4 Modified. The data base used to assess the range accuracy of the AN/BQS-4 and the AN/BQS-4 Modified was data taken at Dabob Bay and at Fleet Operational Readiness Accuracy Check Sites (FORACS) at Guantanamo Bay, Cuba, and San Clemente Island, California. Indications from the limited data available were that the present AN/BQS-4 could be assigned a range error standard deviation of about 4%. Other active sonars, such as the AN/SQS-23 series, have exhibited a range error of about 1% on these same measurement ranges. These data are generally

taken at ship speed of 3 knots and in Sea State 2 or less with the ship going into or with the sea. The result of the examination was that the AN/BQS-4 range accuracy was estimated to be about 4% and the AN/BQS-4 modification was chosen at 2%. The range accuracy assigned to the AN/BQS-4 modified was based on the fact that the AN/SQS-23 had demonstrated that 1% accuracy had been achieved and that the modification to AN/BQS-4 should be comparable to the present AN/SQS-23 in measuring range.

Hence, the AN/BQS-4 was assumed to have a standard deviation of 0.04R and a zero mean error while the AN/BQS-4 modified was assumed to have a standard deviation of 0.02R and a zero mean error.

4.4.2.2 Bearing Systems

Two sources of bearing information are under consideration: The AN/BQR-2B, the AN/BQR-2 (DIMUS) and the PUFFS sonar subsystem.

AN/BQR-2B and AN/BQR-2 (DIMUS). The assessment of bearing errors supplied by the AN/BQR-2B or the AN/BQR-2 ( ) DIMUS was made on data similar to that used for estimation of range errors. The AN/BQR-2B has exhibited a peak local mean error of about 1^{o} at Dabob Bay and FORACS. This error includes a bias error (alignment) and a bearing dependent error. The standard deviation about a best fit curve through the bearing dependent bearing errors was about 0.3^{o} for 80% of the equipments tested at Dabob Bay. Therefore, the AN/BQR-2B was assumed to have a bias of $+1^{o}$ and a standard deviation of 0.3^{o}. The AN/BQR-2 (DIMUS) data was so scarce, that it was assigned a bias error of zero and a standard deviation of 0.25^{o}.

PUFFS. According to the MK48 Torpedo Simulation Model Choice IIB, the theoretical standard deviation of the bearing error of the PUFFS subsystem sonar is:

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$$\sigma_\beta = \left[(0.25)^2 + \sigma_B{}^2 \right]^{\frac{1}{2}} , \qquad (21)$$

where

σ_β = bearing error in degrees;

σ_B = error due to system noise (see PUFFS range error).

The bias error of PUFFS is assumed to be zero.

Each localization subsystem is assumed to have a S/N threshold level, below which the system will return no information. This cutoff is the S/N level associated with the 0.1 probability of detection for infinite observation time for the AN/BQR-2B and 2 (DIMUS); the S/N level corresponding to a 1 min. signal integration time for PUFFS; and the single ping 0.5 probability of detection S/N level for the AN/BQS-4 and AN/BQS-4 (MODIFIED).

Further, each localization subsystem is assumed to operate only in a certain sector of a 360^o circle. The sector in which the system is able to return no useful information is termed the blind spot of the system. This blind spot occurs due to the physical location of the sonar system in question (i.e., a sonar located on the nose of the ship cannot detect a target aft). All systems except PUFFS are assumed blind in a 30^o sector astern.

The PUFFS system presents a special case, as it is mounted atop the ship and is designed to look abeam. Data gathered more than 40^o from abeam is extremely error prone (see formulas for error in this section). Therefore, the blind spot of PUFFS consists of the sectors outside $\pm$ 40^o from abeam. Also, PUFFS is assumed to have a range limit beyond which it provides no useful information. From the OPEVAL data, this range was chosen as 18,000 yds.

4.4.3. <u>Classification Systems</u>

The classification system is the AN/BQH-2C, which serves as an information collection system in conjunction with the AN/BQR-2B or the AN/BQR-2 (DIMUS) sonar systems. The information available on this classification system is scarce*, but the following approach was selected for this study.

If the signal-to-noise level at the input to the BQH-2C is at least -6dB for a period of 20 min., there is a 0.90 probability of correct classification. It is assumed that if there is a 0.90 probability of correct classification, then the target has been correctly classified.

4.4.4 <u>Signal-To-Noise Calculation</u>

The calculation of the signal-to-noise ratio at the beamformer output is of fundamental importance to subsystem performance.

The calculation of signal-to-noise is divided into two basic calculations - one for passive subsystems and one for active systems. The similarity of the calculations will be apparent.

The quantities which determine the signal and noise levels at the beamformer output for a passive sonar are defined below.

(1) T(f) denotes the spectral density of the acoustic energy radiated by the target referred to one yard from the target;

(2) H(f) denotes the spectral propagation loss of the acoustic energy which leaves the target and travels to the receiving array. This quantity includes the effects of multi-

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*MIL-S-24018 (SHIPS), Military Specification for Sonar Set AN/BQH-2C, 16 August 1966.

path arrivals and the beam deviation loss for each arrival;

(3) N(f) denotes the spectral density of the environmental noise field;

(4) A(f) denotes the frequency response of the system filters; and

(5) $\Delta(f)$ denotes the array directivity index for the isotropic environmental noise field.

The noise power, N_a, at point A in the block diagram is calculated from

$$N_a = \int_{f_o}^{f_o + B} A(f)N(f)\Delta(f)\, df\ , \qquad (22)$$

in which f_o is the lower band edge, and B is the receiving bandwidth. Since the input equalizer filters for the subsystems are usually designed to achieve maximum "prewhitening," the integrand above is approximately constant. This being the case, the result of the integration is:

$$N_a = B\ A(f_c)N(f_c)\Delta(f_c)\ , \qquad (23)$$

for which f_c is the effective band center, defined as $[f_o(f + B)]^{\frac{1}{2}}$.

To obtain the signal power S_a at point A in the block diagram, it is necessary to evaluate the integral

$$S_a = \int_{f_o}^{f_o + B} A(f)\ H(f)\ T(f)\ df\ . \qquad (24)$$

The integral has been approximated by

$$S_a = \left[B\ A(f_c)\ T(f_c)\right]\left[\frac{1}{B}\int_{f_o}^{f_o + B} H(f)\ df\right]\ . \qquad (25)$$

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The second bracket in the above equation, denoted by L_e, represents the effective transmission loss at the beamformer output averaged over the subsystem bandwidth. This quantity is computed through a numerical integration over H(f). The spectral propagation loss function, H(f), is computed for a particular velocity profile as a function of range, source depth, and receiver depth, using a ray tracing propagation loss model in which the directivity pattern of the subsystem is utilized to account for the beam deviation loss associated with the direction of arrival of each ray. Examples of the spectral propagation loss curves used in the analysis are shown in Figures 18 through 20. The beam patterns were computed at the subsystem center frequency, f_c, using the actual subsystem array configuration*. The particular velocity profile utilized by the propagation loss model for the Norwegian Sea is given in Figure 21.

The ratio of average signal power, S_a, to average noise power, N_a, denoted by $(S/N)_a$, has been determined using the equation:

$$(S/N)_a = \frac{S_a}{N_a} = \frac{T(f_c)\, L_e}{N(f_c)\, \Delta(f_c)} \quad . \tag{26}$$

It is more convenient to represent the signal-to-noise ratio in dB, in which case the equation becomes:

$$10 \log (S/N)_a = 10 \log T(f_c) + \log L_e - 10 \log N(f_c) - 10 \log \Delta(f_c). \tag{27}$$

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*SS/SSN Sonar Improvement Program Analysis (U) TRACOR Document Number RL/67-025-C of May 1967 (CONFIDENTIAL).

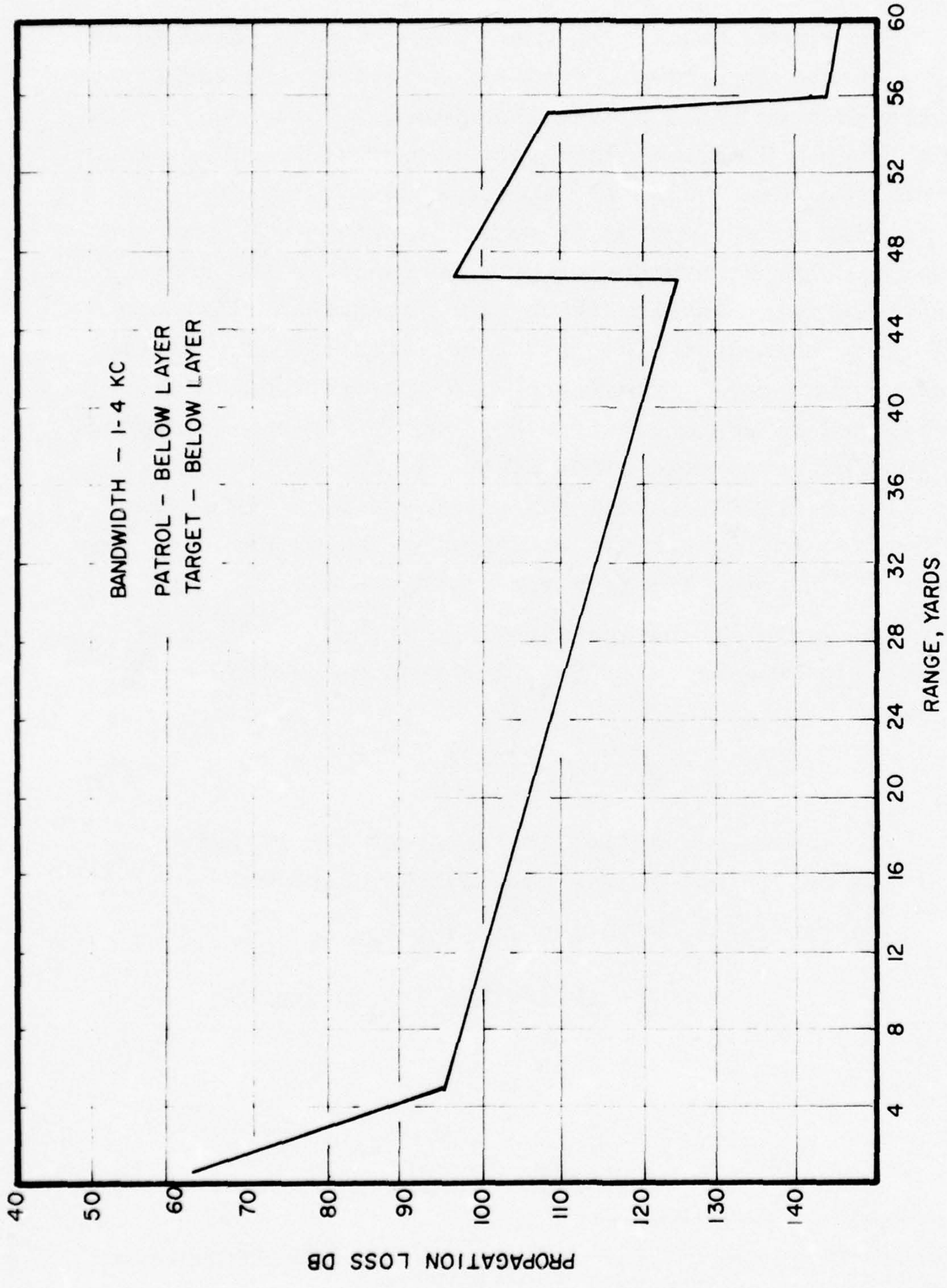

FIG. 18 — PROPAGATION LOSS CURVES - BELOW LAYER

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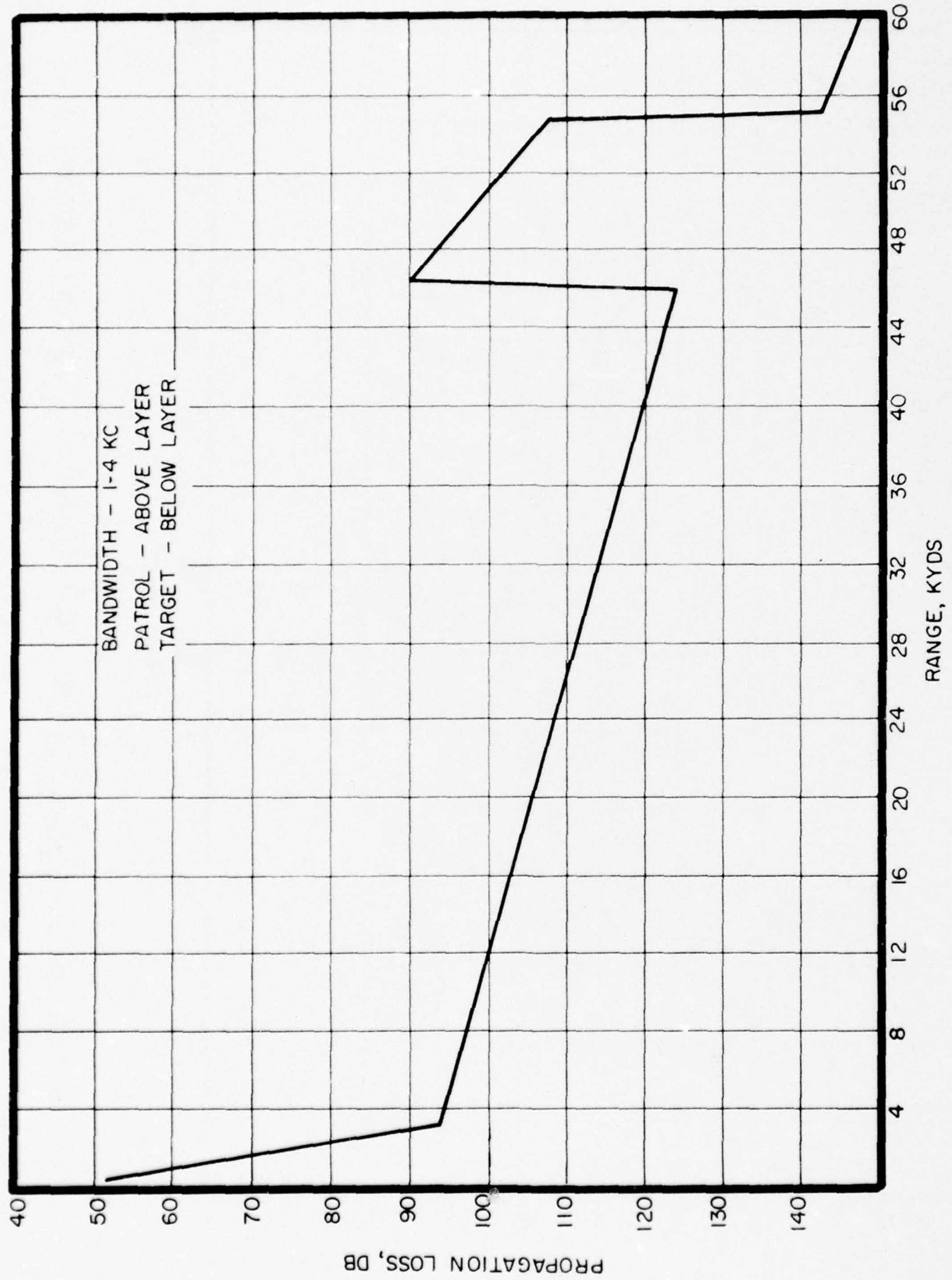

FIG. 19 - PROPAGATION LOSS CURVES- CROSS LAYER

TRACOR DWG. A6-62-208
9/11/67 WILLIAMS /SL

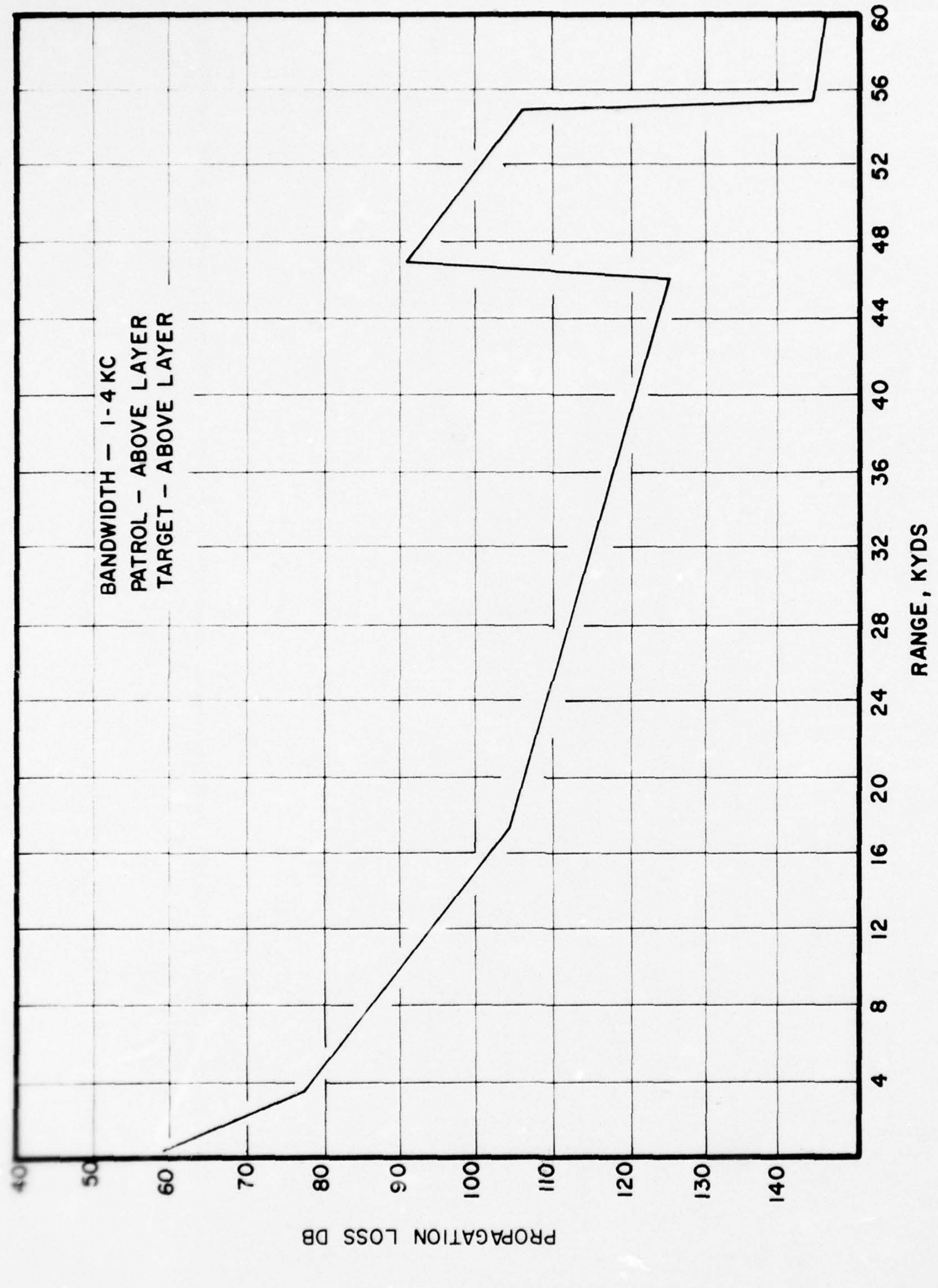

FIG. 20 — PROPAGATION LOSS CURVES — ABOVE LAYER

TRACOR DWG. A6-62-207
9/12/67 WILLIAMS / JK

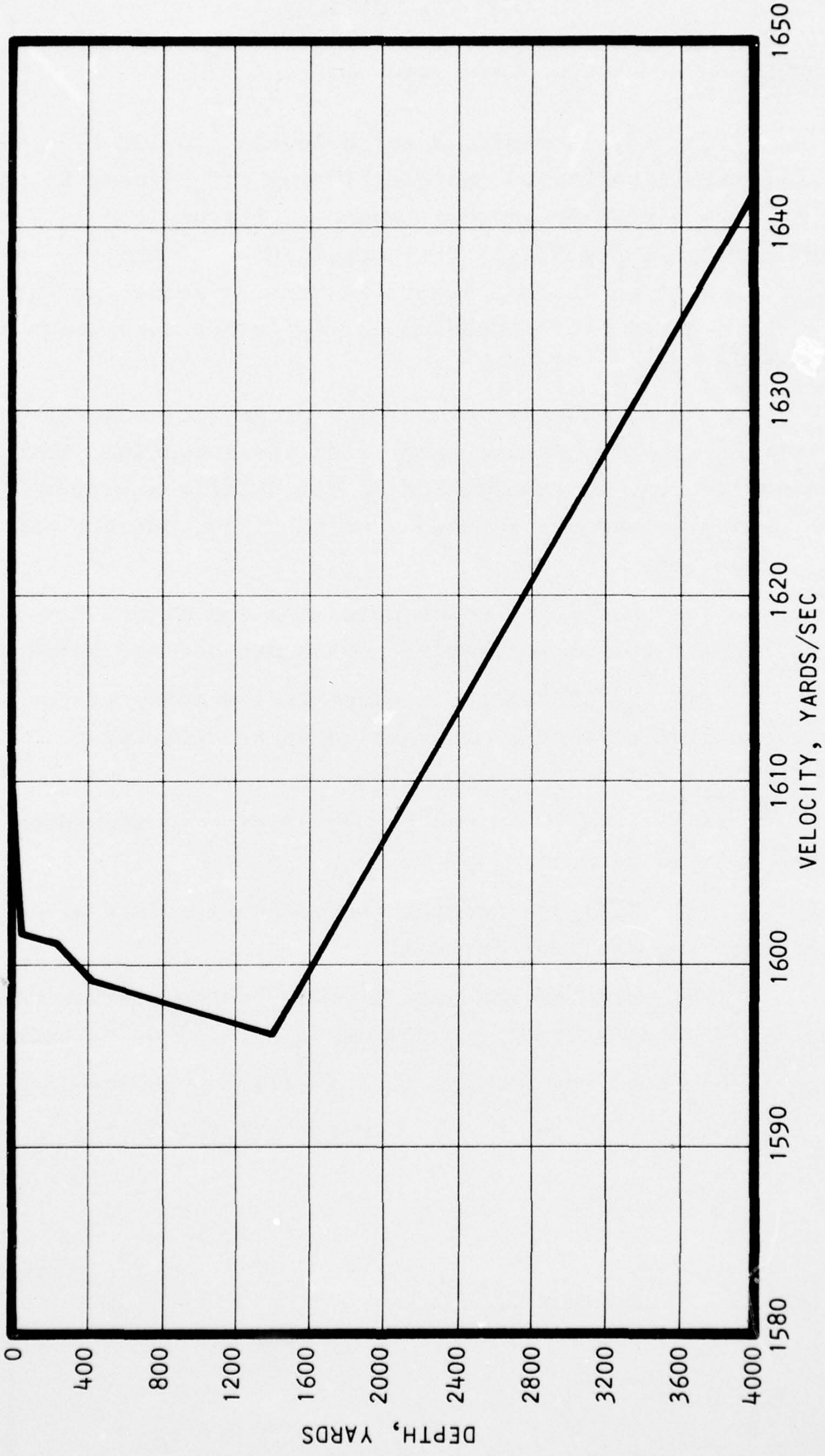

FIG. 21 - SOUND VELOCITY PROFILE USED IN SIMULATION

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The target radiated noise levels [10 log $T(f_c)$] and the subsystem directivity indices [10 log $\Delta(f_c)$] used in the analysis are listed in another report*. The environmental noise levels [10 log $N(f_o)$] were obtained by adding the self-noise values given in that report to the sea state four noise level at f_c given by the Knudsen curves (after correction for the depth of the receiver).

The calculation of $(S/N)_a$ for an active sonar is very similar to the passive case, with the exception that the signal energy is transmitted at essentially a single frequency which is Doppler shifted when received, but not particularly broadened.

The quantities which determine the signal level at the beamformer output for active sonars are defined below.

(1) $S(f_c)$ denotes the *spectral* density of the acoustic energy emitted by the active sonar referred to one yard from the emitter;

(2) $\Delta T(f_c)$ denotes the array directivity index for the transmitted signal;

(3) $TS(f_c,\theta)$ denotes the target strength as a function of the angle of arrival θ.

The ratio of the signal power to the average noise power has been determined (in dB) using the following equation:

$$10 \log (S/N)_a = 10 \log S(f_c) + 10 \log \Delta T(f_c) + 10 \log TS(f_c,\theta) - 10 \log N(f_c) - 10 \log \Delta(f_c) + 20 \log L_e - 10 \log B. \tag{28}$$

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*ibid

The source levels [10 log $S(f_c)$], the transmission directivity indices [10 log $\Delta T(f_c)$], the receiving directivity indices [10 log $\Delta(f_c)$] and the bandwidth of the receiver [10 log B] have been listed* for each subsystem. The target strength data [10 log $TS(f_c,\theta)$] was not available as a function of aspect angle θ. Hence, the target strength was approximated as a constant for all aspect angles:

$$10 \log TS(f_c) = 15 \text{ dB} . \qquad (29)$$

It should be observed that, in the computer program, propagation loss is stored as a negative number, receiving directivity indices are negative, and depths are negative. Further, there are three propagation loss tables stored for each subsystem. The tables represent the cases for both ships above the layer, one above and one below, and both ships below the layer.

The above discussion is based on the assumption that the effect of the beamformer on the acoustical signal field and the effect on the acoustical noise field can be considered independently. This is true for a linear beamformer. In the case of a non-linear beamformer (a DIMUS system, for example), this independent treatment of signal field and noise field to predict the (S/N) ratio at the output of the beamformer may not be valid. This problem is currently under investigation.

4.4.5 Tracking Subsystems

In the simulation of the Penetrator's course through the barrier, it is assumed that he will perform some random evasive maneuvers about a predetermined straight line course. Therefore, there are two types of tracking problems for the patrol submarine. The first tracking problem is to determine

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*Ibid

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the base course about which the Penetrator is maneuvering. This is a long term problem in which the Penetrator must be tracked for several legs of his maneuver course.

The second tracking problem arises in conjunction with the launch of a weapon at the target. In this case, the patrol submarine is interested in the present course and speed of the Penetrator, rather than the base course. This second problem is a short-term tracking problem in which the track is reinitialized each time the Penetrator is observed to turn.

A satisfactory approximation to the resolution of both tracking problems is obtained by making a linear hypothesis concerning the motion of the target for both tracking situations. We assume, thereby, that the target course in the barrier coordinate system is the following (the broken line in Fig. 22 represents the base course, the solid line the maneuver course):

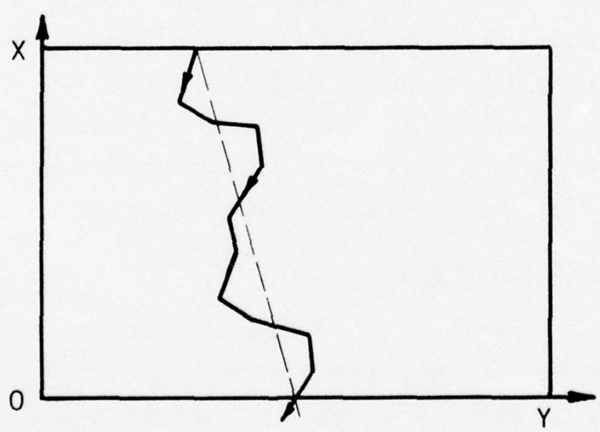

FIG. 22. TRANSITOR'S COURSE THROUGH BARRIER

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The mathematical description of the problem of fitting a linear function to a set of observable data is to postulate the relation

$$\begin{aligned} X &= \alpha_1 + \alpha_2 t + e \\ Y &= \alpha_3 + \alpha_4 t + e \end{aligned} \tag{30}$$

where:

X = the random variable corresponding to the X-coordinate of the target;

Y = the random variable corresponding to the Y-coordinate of the target;

t = non-random, observable variable time;

e = random error of mean zero.

α_1, α_2, α_3, α_4 = unknown parameters

It is shown* that the minimum-variance, unbiased estimators of the unknown parameters (α_1, α_2, α_3, and α_4) can be obtained from a set of data $\left\{(X_i, Y_i, t_i)\right\}_1^n$ by the following relations:

$$\alpha_2 = \frac{\sum_{i=1}^{n} (X_i - \overline{X})(t_i - \overline{t})}{\sum_{i=1}^{n} (t_i - \overline{t})^2}, \tag{31}$$

$$\alpha_1 = \overline{X} - \alpha_2 \overline{t},$$

where $$\overline{t} = \frac{1}{n} \sum_{i-1}^{n} t_i , \quad \overline{X} = \frac{1}{n} \sum_{i=1}^{n} X_i ,$$

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*Mood, A. M. and Graybill, F. A., Introduction to the Theory of Statistics, McGraw-Hill Book Company, Inc., New York, 1963.

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and

$$\alpha_4 = \frac{\sum_{i=1}^{n} (Y_i - \overline{Y})(t_i - \overline{t})}{\sum_{i=1}^{n} (t_i - \overline{t})^2},$$

$$\alpha_3 = \overline{Y} - \alpha_4 \overline{t}, \tag{32}$$

where $\overline{t} = \frac{1}{n} \sum_{i=1}^{n} t_i$, $\overline{Y} = \frac{1}{n} \sum_{i=1}^{n} Y_i$.

It is clear that the assumption that e has a mean zero and is normally distributed implies that X has a mean $(\alpha_1 + \alpha_2 t)$ and a standard deviation about that mean of σ_x. The minimum-variance, unbiased estimate of σ is shown in the same reference to be

$$\sigma_x = \left[\frac{1}{n-2} \sum_{i=1}^{n} (X_i - \alpha_1 - \alpha_2 t_i)^2\right]^{\frac{1}{2}} . \tag{33}$$

Similarly, Y has a mean of $(\alpha_3 + \alpha_4 t)$ and a standard deviation σ_y which is found to be estimated by

$$\sigma_y = \left[\frac{1}{n-2} \sum_{n-2}^{n} (Y_i - \alpha_3 - \alpha_4 t_i)^2\right]^{\frac{1}{2}} . \tag{34}$$

These estimates of σ provide a measure of the "goodness of fit" of the lines to the data. It also should be noted that the physical interpretation of the α's is that

α_1 = best estimated X-position of the target at the start of the track ($t_i = 0$);

α_2 = best estimated X-velocity of the target during the tracking interval;

α_3 = best estimated Y-position of the target at the start of the track ($t_i = 0$);

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α_4 = best estimated Y-velocity of the target during the tracking interval.

These parameter estimates can then be used by the TACTIC routine to determine the estimated course and speed of the target in the barrier coordinate system.

The tracking routines are set up to provide current estimates of target position and speed. These estimates are based on all information stored in the track and are found using the following equations:

$$X = \alpha_1 + \alpha_2 t,$$
$$Y = \alpha_3 + \alpha_4 t, \tag{35}$$
$$V = (\alpha_2^2 + \alpha_4^2)^{\frac{1}{2}},$$

where

X is the current estimated X-coordinate of the target,
Y is the current estimated Y-coordinate of the target,
V is the current estimated speed of the target,
t is the time since the track was initialized.

4.4.6 Computation of Ambush Parameters

To achieve an ambush, the patrol submarine must choose a position in the barrier at which he will attempt to attack the transitor. This choice depends on the following constraints:

1. He must reach the ambush position before the transitor enters his detection region;

2. He must not leave the barrier region.

The selection of the ambush course and speed depends on the current position, course, and speed of the transitor, and upon the current position of the patrol submarine. If the transitor is assumed to be a diesel-electric submarine, the ambush is attempted at the position where it is believed that he will next snorkel.

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The diagram (Fig. 23) of the problem establishes the technique used in this program to determine an ambush position. It should be noted that the technique used here is not necessarily that used by the fleet nor is it the best implementation of the ambush doctrine.

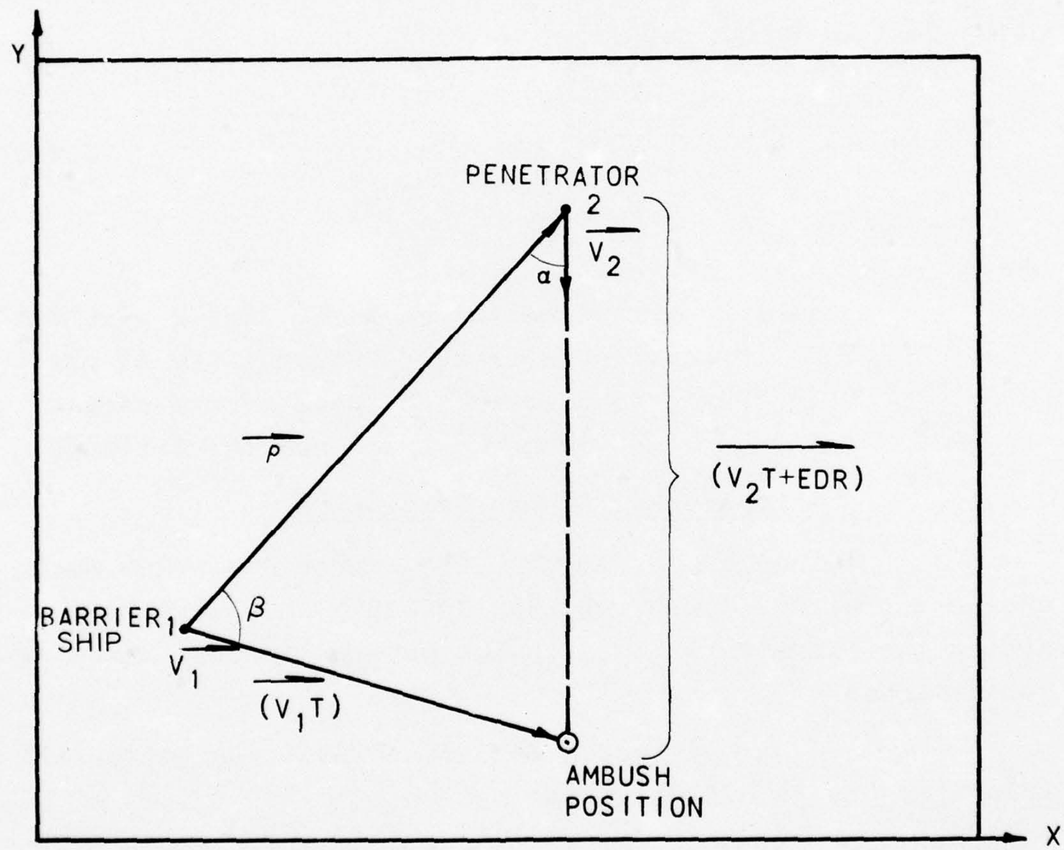

FIG. 23 DIAGRAM OF AMBUSH COMPUTATION PARAMETERS

In the diagram, the patrol submarine (Barrier Ship) is labeled with 1, the transitor (Penetrator) with 2, $\vec{\rho}$ is the range vector between the ships, $\vec{V}_2$ is the velocity vector of the transitor, and EDR is the detection range of the patrol submarine.

Clearly, the problem is to find the pair (V_1,T) which satisfies the criteria, and once (V_1,T) is found, to compute the course β.

If the transitor is assumed to be a diesel-electric, an estimated time until next snorkel is provided, namely ETS, and ambush is attempted at a specified velocity V_{min} using that time. The following inequality must be satisfied if ambush is possible at this time and velocity:

$$V_{min}(ETS) \geq |\vec{\rho} + (\overrightarrow{V_2\ ETS + EDR})| . \tag{36}$$

If ambush is impossible, or if the predicted ambush point is outside the barrier, the velocity is increased by a fixed amount to V_1, and ambush is attempted at the original ETS.

The process continues until either a pair (V_1,ETS) satisfies the ambush criteria, or until V_1 equals the maximum velocity of the ship and the ambush criteria are still not satisfied. In the latter case, a flag is set to indicate no ambush.

If the equality is satisfied, the law of cosines is used to find the course angle β:

$$\cos\beta = \frac{(V_1T)^2 + |\vec{\rho}|^2 - (\overrightarrow{V_2T + EDR})^2}{2(V_1T)\ |\vec{\rho}|} . \tag{37}$$

If the transitor is assumed to be a nuclear submarine, no time until next snorkel can be chosen, and some initial estimate T_o of a time to intercept must be determined. This is accomplished in the following manner:

$$\alpha = \pi - \cos^{-1}\left[\vec{\rho} \cdot \vec{V}_2/(|\vec{\rho}|\ |\vec{V}_2|)\right] ,$$

$$d_1 = |\vec{\rho}| \cos \alpha , \tag{38}$$

$$T_o = \frac{d_1}{V_1} , \text{ where } V_1 \text{ is initially } V_{min},$$

and the same inequality is again tested:

$$d_1 \geq |\vec{\rho} + \overrightarrow{(V_2 T_o + EWR)}| . \tag{39}$$

If the inequality is not satisfied, the estimate T_o is increased (by 10 min) and the coordinates of the predicted ambush point are computed, etc.

The ambush parameters (V_1,T) are finally determined just as before, and the angle β selected as in the previous discussion.

If no ambush can occur even at the maximum speed of the patrol submarine, the program prints a message and sets a flag indicating this fact.

4.4.7 Torpedo Model

To estimate the torpedo intercept probability the ORL CHOICE IIB MK-48 torpedo model* was used. Due to its complexity a complete description cannot be given here. However, it will be useful to outline this model as it relates to the problem under consideration.

The CHOICE IIB model is essentially a simulation of the events which occur from the instant of torpedo launch to intercept, applied to only one particular mode of use; namely, it is assumed that the torpedo is fixed in the lead intercept mode. As designed, the model takes into account the following

*ORL Report - R. Greenstone and J. McCutcheon, "CHOICE, A Probabilistic Model of an Advanced Torpedo(U)", Tech. Memo. File No. TM412.2711-71, May 1966, Contract NOW 65-0123-d.

factors:

(a) Target evasion upon detection of running torpedoes, including reaction time.

(b) The errors in range and bearing data provided to the torpedo from the submarine's sonar system during the wire guided phase.

(c) The noise characteristics of the torpedo and the target.

(d) The torpedo sonar systems (active and passive).

(e) The torpedo search and runout speeds and the search pattern.

(f) A single zig-zag maneuver on the part of the target.

(g) Command guidance capability. (During the wire guided phase one torpedo guidance change is allowed).

(h) Torpedo fuel limitations.

(i) Target speed and maneuvering capability.

(j) Wire length.

(k) Target "baffle" region effect.

The essentials of the model can be understood by referring to Figure 24. Thus, torpedo launch occurs based on the estimated target track and speed, and guidance is provided based upon the attack submarine's sonar system, where it is assumed that the target always is at the center of the position indicated by the sonar for these purposes. After some elapsed time the target can exercise a single turn maneuver and the torpedo can be appropriately redirected. Further, the target may have detected running torpedoes and hence react as illustrated.

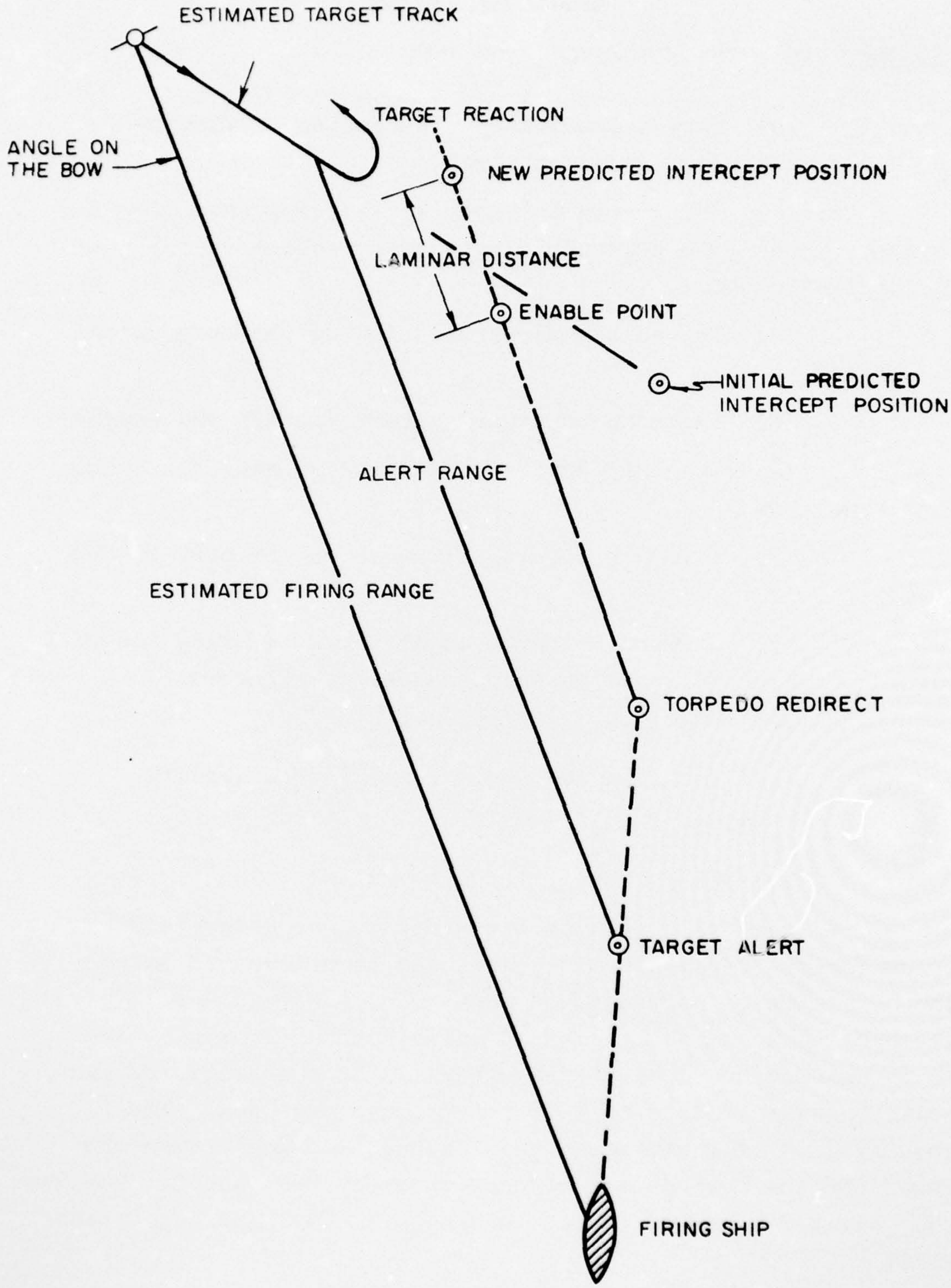

FIG. 24 – DIAGRAM OF TORPEDO MODEL INTERCEPT

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The torpedo heads initially to a precomputed point based on the initially predicted target intercept position, or to a newly computed position if torpedo redirect occurs. At that point the torpedo commences its search using either an active or passive sonar system. The target position at this point in time is taken to lie in a region of space defined by the range and bearing errors associated with the submarine sonar, in accordance with a normal probability distribution function of both range and bearing. The consequent intercept probability, taking into account this position distribution and the other factors noted earlier, is then calculated.

The CHOICE IIB model has been slightly altered for the purposes of this program. These changes include the following:

1. All signal or noise calculations not relating exclusively to the MK-48 torpedo apparatus are handled by the signal-to-noise routines discussed in this report.

2. The calculation of propagation loss, ship self-noise, ship passive and active signal, and signal-to-noise ratio are handled in routines exterior to the CHOICE IIB model.

The above changes produce more realistic S/N levels than did the original CHOICE IIB model, and hence produce more realistic probability of kill results.

4.5 COMMAND AND CONTROL (TACTIC)

The routine TACTIC is entered to evaluate the status of the simulation as provided by the SUBSYS information and to make decisions required by this information. The decisions are made in accordance with preassigned doctrinal principles for each boat. A detailed description of the doctrinal principles and their implementation in the simulation follows.

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THE DEVELOPMENT OF A GENERAL COMBAT SIMULATION MODEL.(U)

SEP 67 J D STUART, F W WEIDMANN, S LAGRONE N00024-67-C-1572

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4.5.1 Doctrinal Principles

The doctrinal principles employed in this computer simulation were outlined in discussions with CNO. For the patrol submarine the doctrinal principles are:

(1) In the event that the patrol submarine achieves a detection, it will, subject to certain constraints, carry out an attack on the enemy submarine in accordance with the following three attack principles, which are selected in the order presented:

a. "Ambush" - the patrol submarine attempts to reach a position in the path of the target submarine in such a way that torpedo launch can be accomplished from a range of choice without being detected.

b. "Tail Chase" - the patrol submarine attempts to reach a position in the "baffle" region of the target submarine in such a way that torpedo launch in this region can be accomplished from a range of choice without being detected.

c. "Close and Attack" - the patrol submarine elects an approach tactic which enables torpedo launch to be accomplished in minimum time.

(2) The constraints placed on the patrol submarine are:

a. The patrol submarine shall, to the extent possible, avoid detection by the enemy prior to torpedo launch.

b. In the event that detection by the enemy is believed to have occurred, the patrol submarine shall employ evasive tactics.

c. The patrol submarine will not leave its forward area patrol region (the barrier).

The transitor doctrine is purely evasive in nature. Thus, if the transitor detects the patrol submarine, evasive tactics are employed.

This tactical doctrine differs somewhat from that used in TRACOR's SS/SSN Preliminary Cost-Effectiveness Analysis. The analytical nature of that analysis made it unnecessary to consider constraints b) and c) above.

For attack principles a) and b), that analytical study used "torpedo launch . . . from a position of choice" rather than "torpedo launch . . . from a range of choice." The analytical study assumed perfect tracking information. Although the computer simulation addressed the tracking problem, there are enough uncertainties in the accuracy of the treatment to make unwarranted an attempt to maneuver into a position of choice before weapon launch.

It should be emphasized that the detailed tactics employed in the computer simulation are an interpretation of the doctrinal principles outlined by CNO. They are not necessarily the tactics employed by U. S. submarines nor is it necessarily recommended that they be so employed.

4.5.2 Implementation of Tactical Doctrine in the Simulation

4.5.2.1 Introduction. The tactics employed by a submarine during the course of time may be thought of as the implementation of the submarine's tactical doctrine subject to the cumulative information available to the decision maker on board that submarine. This particular implementation does not necessarily represent that actually used by the fleet. For programming purposes it is convenient to separate the tactics of each submarine into a number of parts. Each part is characterized by the state of the cumulative information available and the course of action

required by that submarine's tactical doctrine given that information. Each of these divisions of the tactics program is called a tactical situation. At each simulated time point the information available to each ship is reevaluated and the decision is made either to remain in the current tactical situation or to transfer to another tactical situation.

Nine tactical situations are required for the patrol submarine. Two are required for the transitor. Tables IV and V contain a brief outline of these tactical situations, and detailed flow charts are contained in the Appendix. A detailed description of each tactical situation will now be given.

4.5.2.2 Tactical situations of patrol submarine. Overriding all of the tactical considerations of the patrol submarine is the detection of an active sonar ping. In the event that a ping is detected the decision maker assumes that the ping is a result of the use of active sonar by an enemy submarine. He further assumes that the enemy would only employ active sonar just prior to a weapon launch. Therefore, in the event of ping detection, the patrol submarine turns to a direction opposite that in which the ping was received, dives to maximum depth and runs at maximum speed.

4.5.2.2.1 Tactical Situation No. 1 - No Detection Has Occurred. This is the tactical situation existing prior to any detection. The patrol submarine is completely unaware of any intruder which might be in its vicinity. The patrol submarine proceeds on its preassigned patrol pattern with its passive detection system in operation. The existing simulation provides for two types of patrol paths: (1) back and forth along a straight line parallel to the X-axis (See Fig. 10) and (2) a circular path with center at any point and with an arbitrary radius. On both of these paths the submarine may proceed at any fixed depth and move with any fixed speed. The turn at the end of each patrol segment in the straight line case is

TABLE IV. SUMMARY OF TACTICS OF PATROL SUBMARINE

	TACTICAL SITUATION								
	1	2	3	4	5	6	7	8	9
1. Information State	No Detection	Contact Maintained	Alerted Contact Lost	Alerted Contact Lost	Contact Maintained Satisfactory Fire Control Solution Available	Approximate track established. Contact may or may not be maintained.	Contact Maintained Approximate track established.	Estimated to be within enemy's detection and weapon range. Contact may or may not be maintained.	Contact Maintained Approximate Track Established
2. Objective	Detect Intruder	Gather data necessary to make mode of attack decision	Regain Contact	Regain Contact	Fire Torpedo	Ambush Contact	Tail Chase	Evade	Close and Attack
3. Course of Action	Patrol	Move so as to close the contact with PUFFS bearing on contact	Patrol	Steer in Direction of Last Contact	Fire Torpedo	Travel to Ambush pivot point the approach target. Reacquire contact if necessary.	Steer so as to approach target from rear with PUFFS bearing on target.	Steer in a direction opposite to that of contact, run at maximum depth and maximum speed.	Steer so as to close the target at maximum rate for preassigned speed with PUFFS bearing on target.
4. Occurrences which may require alteration or termination of course of action prior to reaching objectives (See Table VI)	1,2	1,2,3,4	1,2	1,2		1,2,3,4,5	2,3,4,5	3	2,3,4,5

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TABLE V. SUMMARY OF TACTICS OF TRANSITOR SUBMARINE

	TACTICAL SITUATION	
	1	2
1. Information State	No Detection	Detection of another ship has occurred. Contact may or may not be maintained.
2. Objective	Transit barrier Region	Evade
3. Course of Action	Transit Region	Steer in a direction opposite t. that of contact, run at maximum depth and maximum speed.
4. Occurrences which may require alteration or termination of course of action prior to reaching objectives (See Table C-VI)	1	

TABLE VI. OCCURRENCES REQUIRING ALTERATION OR TERMINATION OF COURSE OF ACTION PRIOR TO REACHING OBJECTIVE

OCCURRENCE	ACTION
1. Submarine is required to snorkel.	1. Submarine snorkels
2. Patrol submarine reaches boundary of barrier	2a. Submarine takes new course so as to not cross boundary while proceeding to objective or, 2b. submarine fires torpedo at target
3. Contact is lost	3a. Submarine maneuvers in an effort to regain contact 3b. Submarine fires torpedo at target if fire control solution is available or, 3c. Evade
4. Patrol submarine is estimated to be within enemy's assumed detection range and weapon's range.	4a. Fire torpedo if a fire control solution is available or, 4b. Evade
5. Contact makes an unexpected course change	5. Fire torpedo if a fire control solution is available or, patrol if range is closing or, close and attack if range is opening.

accomplished by rotating the heading of the submarine through 180°. All other turn effects are neglected.

If the patrol submarine is a diesel-electric it snorkels in accordance with some preassigned snorkeling scheme. In the current simulation the submarine snorkels with some preassigned frequency for some preassigned duration. For example snorkeling begins at times $t_0 + nT_1$ and ends at times $t_0 + nT_1 + T_2$; t_0 is a reference time, T_1 is the snorkeling period, T_2 is the snorkeling duration and $n = 1,2,3,. . . .$ More elaborate snorkeling schemes can easily be incorporated into the simulation.

Tactical Situation No. 1 is terminated upon the patrol submarine's detection of an intruder, and the patrol submarine enters Tactical Situation No. 2.

4.5.2.2.2 Tactical Situation No. 2 - Detection has occurred, gather information for tactical decision. In this Tactical Situation, the objective of the patrol submarine is to gather information sufficient to allow him to localize, classify, and select the appropriate mode to attack the intruder. If an accurate classification cannot be made, the decision maker in the patrol submarine will assume that the intruder is an enemy transitor. Thus the paramount objective of this Tactical Situation is to track the intruder. In this Tactical Situation the patrol submarine maneuvers on those courses and at those speeds necessary to obtain the intruder's track, and continues to do this either until a track is obtained and a decision can be made, or until circumstances force the discontinuance of this action. The actions of the patroller are at all times subject to the constraints set forth in the doctrinal principles.

Initial Information

Upon entering this Tactical Situation the sonar systems of the patrol submarine provide only two pieces of information: (1) a detection has occurred and (2) the approximate bearing of the intruder. Both of these pieces of information are provided by the detection subsystem. In this simulation, however, the decision maker in the patrol submarine is provided with additional information. This additional information is an estimate of both his and the enemy's detection range, an estimate of the enemy's speed, and an estimate of the enemy's weapon range. These estimators are input parameters to the simulation and are an approximation of the experience and intelligence of the decision maker. At the time of detection the decision maker in the patrol submarine should be able to make at least a gross estimate of the range of the contact. If the decision maker is assumed to have recent bathymetric data available, then he might be able to make a rather accurate estimate of the range of the contact. Thus, the ability of the decision maker to estimate the range to the contact is represented by the accuracy of that input parameter.

Initial Course and Speed of Patrol Submarine

Since only a bearing is available at the time that Tactical Situation No. 2 is entered, the decision maker in the patrol submarine assumes that the contact is an enemy submarine attempting to transit the barrier. He further assumes that if the contact is in the northward direction then the transit is from north to south, and conversely if the contact is in the southward direction. That is, it is assumed that the supposed transitor has not passed the patrol submarine in the barrier. The patrol submarine in the current simulation is equipped with the PUFFS (AN/BQG-4) passive ranging subsystem. This subsystem cannot provide accurate range information unless the target

bearing is within about 40° either side of the beam of the ship upon which it is mounted. Therefore, upon entering Tactical Situation No. 2 the patrol submarine takes a course such that the contact bears either 70° or 290° relative in order to close on the contact at a moderate rate and to bring PUFFS to bear upon the contact. The speed of the patrol submarine during this phase of the tactics may be any preselected value.

During this Tactical Situation the estimate of the range to the contact is made continuously. The methods of obtaining this estimate are, in order of preference:

(1) Computation using the last range provided by PUFFS and the estimate of the intruder's speed.

(2) If contact has been maintained for 45 minutes, the estimated range is assumed to be 70% of the exact range. A range estimate of this accuracy should be obtainable with a bearings only solution in 45 minutes.

(3) Computation using the estimated detection range of the patrol submarine and the estimated speed of intruder.

The estimated range to the contact is used frequently in this Tactical Situation.

The classification subsystem (AN/BQH-2C) is continuously interrogated during the course of this Tactical Situation. If this subsystem fails to provide information the intruder is assumed to be an enemy transitor.

Course and Speed Alterations

The patrol submarine continues on the initial course at the initial speed and attempts to compute the track of the other submarine until one of the following events occurs:

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(1) The patrol submarine reaches an edge of the barrier. If this occurs the patrol submarine changes its heading so as to remain in the barrier region and to continue to bring PUFFS to bear on the contact.

(2) Contact is lost. If contact is lost and the estimate of intruder's range is less than the estimate of the intruder's detection range and weapon range, the decision maker in the patrol submarine assumed that the intruder is making an attack approach on the patrol submarine and by taking a course 180° from the last bearing of the intruder, going to maximum speed, and diving to maximum depth.

If the estimated range to the contact is not less than the contact's estimated weapon range and if some tracking information is available then the patroller will:

(a) Chase on the last bearing available if the range is opening (Tactical Situation No. 4),

(b) Return to patrol with modified patrol limits if the range is closing and the contact is believed to have been in the convergence zone (Tactical Situation No. 3),

(c) Attempt to compute an ambush course and speed if the range is closing. If ambush is possible the patrol submarine proceeds to the ambush point (Tactical Situation No. 6). If it is impossible to compute an ambush course and speed the patrol submarine returns to patrol with modified patrol limits (Tactical Situation No. 4).

If the estimated range to the contact is not less than the contact's estimated weapon range and no tracking information is available, then the patrol submarine returns to patrol with modified patrol limits.

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(3) The estimated range to the contact is less than the contact's estimated detection range and estimated weapon range. If this occurs the patrol submarine does one of the following three things:

(a) Fire a torpedo if a fire control solution is available (Tactical Situation No. 5),

(b) Close and attack if intruder is evading (Tactical Situation No. 9),

(c) Evade by turning to the direction opposite to the direction of the contact, diving to maximum depth, and running at maximum speed (Tactical Situation No. 8).

(4) The relative bearing of the contact is no longer within 30^{o} either side of the beam. If this occurs the patrol submarine comes to a new course such that the relative bearing of the contact is either 70^{o} or 290^{o}.

When and if the approximate track of the intruder is established the patrol submarines does one of the following:

(a) If the range is opening the patrol submarine initiates a Tail-Chase Attack (Tactical Situation No. 7).

(b) If the range is closing an attempt is made to calculate an ambush course and speed. If an ambush is possible the patrol submarine proceeds toward the ambush point (Tactical Situation No. 6).

(c) If ambush is not possible then the patrol submarine proceeds to close and attack the intruder (Tactical Situation No. 9).

If the patrol submarine is a diesel-electric submarine the electrical energy remaining in the batteries is constantly monitored. If the remaining energy falls below a preassigned fraction of the maximum possible energy of the batteries then the patrol submarine will execute a quiet snorkel for preassigned duration. In the present simulation the fraction of the remaining electrical energy is maintained at 1.0 so that the patrol submarine never snorkels in this Tactical Situation. The snorkeling provision is included at present to allow for later improvements in the program.

4.5.2.2.3 Tactical Situation No. 3 - Contact lost, patrol. This Tactical Situation occurs when contact has been lost, and when either: (1) no tracking information is available to the patrol submarine, or (2) the detection is believed to have occurred in the convergence zone. The maneuvers of the patrol submarine are similar to those of Tactical Situation No. 1 in that the patrol submarine patrols back and forth along a straight line segment parallel to the X-axis (see Fig. 10). The limits of the patrol path are not the limits used in Tactical Situation No. 1, however. It is assumed that the contact is proceeding through the barrier on a course parallel to the Y-axis of the barrier and in a direction approaching the patrol path of the patrol submarine. Thus, the patrol limits are calculated using the last contact bearing, the last range to contact estimate (see Tactical Situation No. 2 for the method of estimating range to contact), and a distance which specifies the patrol distance either side of the contact's assumed path. The latter distance is arbitrary and is an input to the program. The Y-coordinate of the patrol path is that value of Y reached by the patrol submarine at the time of lost contact plus the time delay associated with entry into Tactical Situation No. 3.

When and if contact is regained the patrol submarine returns to Tactical Situation No. 2 and attempts to obtain the track of the intruder.

If the patrol submarine is a diesel-electric and if the energy remaining in the batteries falls below a preassigned fraction of the maximum battery energy, then the submarine will execute a quiet snorkel for a preassigned period.

4.5.2.2.4 Tactical Situation No. 4 - Contact lost, pursue. This Tactical Situation occurs when contact has been lost and when circumstances make it desirable to move in the direction of last contact. Tactical Situation No. 2 would occur, for example, when contact was lost because of evasive tactics of the enemy.

In this Tactical Situation the patrol submarine maintains a course in the direction of the last contact, and maintains a preassigned speed until either: (1) the patrol submarine reaches its maneuvering limits within the barrier or (2) contact occurs.

If the patrol submarine reaches its maneuvering limits inside the barrier, it takes a new course parallel to the boundary edge and in the general direction of the last contact.

If detection occurs, the patrol submarine proceeds to close and attack the contact, the assumption being that the contact is an enemy, and that the contact is attempting to evade. The close and attack course is computed on the assumption that the range to the contact is the estimated detection range of the patrol submarine, provided the decision maker is the patrol submarine, and that the contact is proceeding directly away from the patrol submarine. The close or attack speed is an arbitrary input variable.

If the patrol submarine is a diesel-electric and if the energy remaining in the batteries falls below a preassigned fraction of the maximum battery energy then the patrol submarine will execute a quiet snorkel for a preassigned period.

4.5.2.2.5 Tactical Situation No. 5 - Fire torpedo. This is the weapon launch Tactical Situation. It is designed to simulate weapon launch and weapon and ship control during the weapon's run. In the current simulation all of these functions are accounted for in the CHOICE IIB MK-48 Torpedo Simulation. Thus Tactical Situation No. 5 merely initializes and calls the CHOICE Subroutine.

4.5.2.2.6 Tactical Situation No. 6 - Ambush. In this Tactical Situation the Ambush mode of attack is carried out. The Tactical Situation is divided into two phases:

a. Travel to the ambush pivot position

b. The attempt to reestablish contact if contact has been lost during the passage to the pivot position.

The actual approach to the target is accomplished in another Tactical Situation (No. 9).

The method of calculating the course, speed, and time required to reach the ambush pivot position has been described. Upon entering this Tactical Situation the patrol submarine changes course and speed as required and dives to a depth sufficient to place the submarine below the thermal layer, if a layer exists. This maneuver reduces the chances of detection by the enemy submarine.

The patrol submarine proceeds on the ambush course at the required speed until the pivot position is reached unless one of the following events happens:

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A. The estimated range to the contact is less than the target's estimated weapon range and detection range. The method of estimating the range to the target is the same as used in Tactical Situation No. 2. If this occurs the patrol submarine will:

(1) Fire weapon if a fire control solution is available. (Tactical Situation No. 5)
(2) Evade by turning to direction opposite to that of the target, going to maximum speed and diving to maximum depth. (Tactical Situation No. 8).

B. The target makes a major course change while contact is maintained. If this occurs the patrol submarine will:

(1) Fire weapon if a fire control solution is available. (Tactical Situation No. 5).
(2) Close and attack if the target is moving away from the patrol submarine. (Tactical Situation No. 9).
(3) Attempt to retrack the target if the target is moving toward the patrol submarine. (Tactical Situation No. 2).

C. Contact has been regained after being lost. If this occurs the patrol submarine will attempt to retrack the target. (Tactical Situation No. 2).

If, upon arrival at the ambush pivot position, contact has been maintained, the patrol submarine immediately begins to close and attack the enemy at minimum speed. (Tactical Situation No. 9).

If contact has been lost, if the patrol submarine is a diesel-electric, and if the energy remaining in the batteries is below a preassigned fraction of the maximum battery energy,

then the patrol submarine will execute a quiet snorkel. The duration of this snorkel is calculated so that the snorkel period will end at the approximate time that useful detection information starts to be received. The snorkeling is carried out as the ship moves in a circular path about the pivot position at minimum speed.

Upon completion of the snorkel period, or upon arrival at the pivot position if no snorkeling is required and contact has been lost, the patrol submarine turns so as to move along the previously computed track of the enemy at a preassigned speed.

The patrol submarine continues on this course at this speed until redetection has occurred or until the barrier boundary is reached. If the patrol submarine reaches the barrier boundary he takes a new course so as to move parallel to that boundary in the same general direction as the previous course. If redetection occurs, he immediately proceeds to close and attack the enemy at minimum speeds. (Tactical Situation No. 9).

4.5.2.2.7 <u>Tactical Situation No. 7 - Tail chase</u>. In this Tactical Situation, the Tail chase mode of attack is carried out. The course taken by the patrol submarine is essentially a bearing rider course. Instead of steering toward the enemy, however, the patrol submarine steers so that the enemy is approximately 60° off the bow. This is done so that PUFFS will provide ranging information.

Initially the patrol submarine takes a course so that the enemy bears $\pm 60^{\circ}$ off the bow and moves at a preassigned speed. The patrol submarine maintains this course and speed until one of the following events happens:

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A. Contact is lost. If this occurs the patrol submarine steers in the direction of last contact at a preassigned speed in an effort to regain contact. (Tactical Situation No. 4).

B. The patrol submarine reaches the boundary of the barrier. If this occurs, the patrol submarine fires a torpedo regardless of the quality of the fire control solution.

C. The enemy's bearing is less than 55° or more than 65° either side of the bow. If this occurs the patrol submarine adjusts course so that the enemy bears 60° off the bow.

D. Tracking information indicates that the range is opening. If this occurs, the speed of the patrol submarine is increased. If it is impossible to increase speed the patrol submarine fires a torpedo regardless of the quality of the fire control solution.

E. The estimated range to the enemy is less than the enemy's estimated weapon range and estimated detection range. If this occurs, the patrol submarine fires a torpedo if a fire control solution is available. If a fire control solution is not available, the patrol submarine evades by turning to a direction opposite to that of the enemy, diving to maximum depth, and running at maximum speed.

F. A fire control solution is available and the estimated range to the target is less than the preassigned maximum firing range. When this occurs the patrol submarine fires a torpedo at the enemy.

The termination by occurence F is the ultimate goal of this Tactical Situation. It should be noted that the torpedo launch may or may not be made when the patrol submarine is in the baffle region of the enemy. Uncertainties in the accuracy of the treatment of the tracking problem make unwarranted any attempt to maneuver into the baffle region of the enemy.

4.5.2.2.8 Tactical Situation No. 8 - Evade. This Tactical Situation occurs when the decision has been made to evade the other submarine. Upon entering this Tactical Situation the patrol submarine turns to a course 180^{o} away from the contact, dives to maximum depth, and runs at maximum speed. The patrol submarine will continue on this course at this speed and depth unless one of the following events happens:

A. The patrol submarine reaches the boundary of the barrier. If this occurs the patrol submarine takes a course parallel to the boundary in a direction away from the last bearing of the enemy.

B. The patrol submarine obtains the bearing of the enemy. He will then change course so that the enemy bears 180^{o} relative. Ordinarily, the enemy will be in the patrol submarine's blind spot.

4.5.2.2.9 Tactical Situation No. 9 - Close and attack. This Tactical Situation occurs when the decision has been made to close the target and fire as soon as a fire control solution is available and the estimated range to the target is less than the maximum firing range. Initially the course taken by the patrol submarine is a modified lead intercept course. That is, the patrol submarine takes a lead intercept course if this course will allow PUFFS to bear on the enemy. If PUFFS will not bear upon the enemy the course is adjusted so that PUFFS will bear. The speed of the patrol may be any preassigned number greater than the speed required to close the lead intercept triangle.

The patrol submarine continues on this course at this speed unless one of the following events happens:

A. The patrol submarine reaches the boundary of the barrier. If this occurs the patrol submarine fires a torpedo regardless of the quality of the fire control solution.

B. Contact is lost. If this occurs, the patrol submarine steers in the direction of last contact at a preassigned speed in an effort to regain contact. (Tactical Situation No. 4).

C. The target does not bear between 55° and 65° either side of the bow. If this occurs a new modified lead intercept course and speed is computed and the patrol submarine takes this new course and speed.

D. The estimated range to the target is less than the estimate of the target's weapon range and detection range. If this occurs, the patrol submarine fires at the target if a fire control solution is available. If no fire control solution is available, the patrol submarine evades by turning to a direction opposite to that of the enemy, diving to maximum depth and running at maximum speed. (Tactical Situation No. 8).

E. A satisfactory fire control solution exists and the estimated range to the target is less than the maximum firing range. When this occurs, the patrol submarine fires a torpedo at the target.

4.5.2.3 Tactical Situations of the Transitor. Overriding all of the tactical considerations of the transitor is the detection of an active sonar ping. As with the patrol submarine, if a ping is detected, the transitor immediately evades by turning to a direction opposite that in which the ping was received, diving to maximum depth and running at maximum speed.

4.5.2.3.1 Tactical Situation No. 1 - No Detection has occurred. This is the tactical situation existing prior to any detection. While in this tactical situation the transitor proceeds to pass through the barrier.

It is not assumed that the transitor is aware of the precise location of the barrier but it is assumed that the transitor is aware that he is in a region of possible enemy activity. Therefore, the transitor carries out precautionary tactics by zig-zagging. This is accomplished by defining a base course, φ_o, a maximum deviation from base course $\Delta\varphi$, and a turn time increment, Δt. At times $t_T + \Delta t$, where t_T is the time of last turn, a new course between $\varphi_o - \Delta\varphi$ and $\varphi_o + \Delta\varphi$ is selected at random. The speed of the transitor is a preselected constant.

If the transitor is a diesel-electric, he snorkels in accordance with some preassigned snorkeling scheme. In the current simulation the transitor snorkels with some preassigned frequency for some preassigned duration. The snorkeling scheme is the same as that employed by the patrol submarine in Tactical Situation No. 1.

When the transitor detects another ship, he assumes that the contact is an enemy and takes immediate evasive action by turning to the direction opposite to that of the contact, diving to maximum depth and running at maximum speed.

4.5.2.3.2 Tactical Situation No. 2 - Evade. This Tactical Situation occurs when the decision has been made to evade the contact. The patrol submarine continues on the evade course selected in Tactical Situation No. 1, at maximum depth and maintains maximum speed unless the transitor obtains the bearing of the enemy. If this occurs, the transitor will change course so that the contact bears 180° relative. Ordinarily the enemy will be in the transitor's blind spot.

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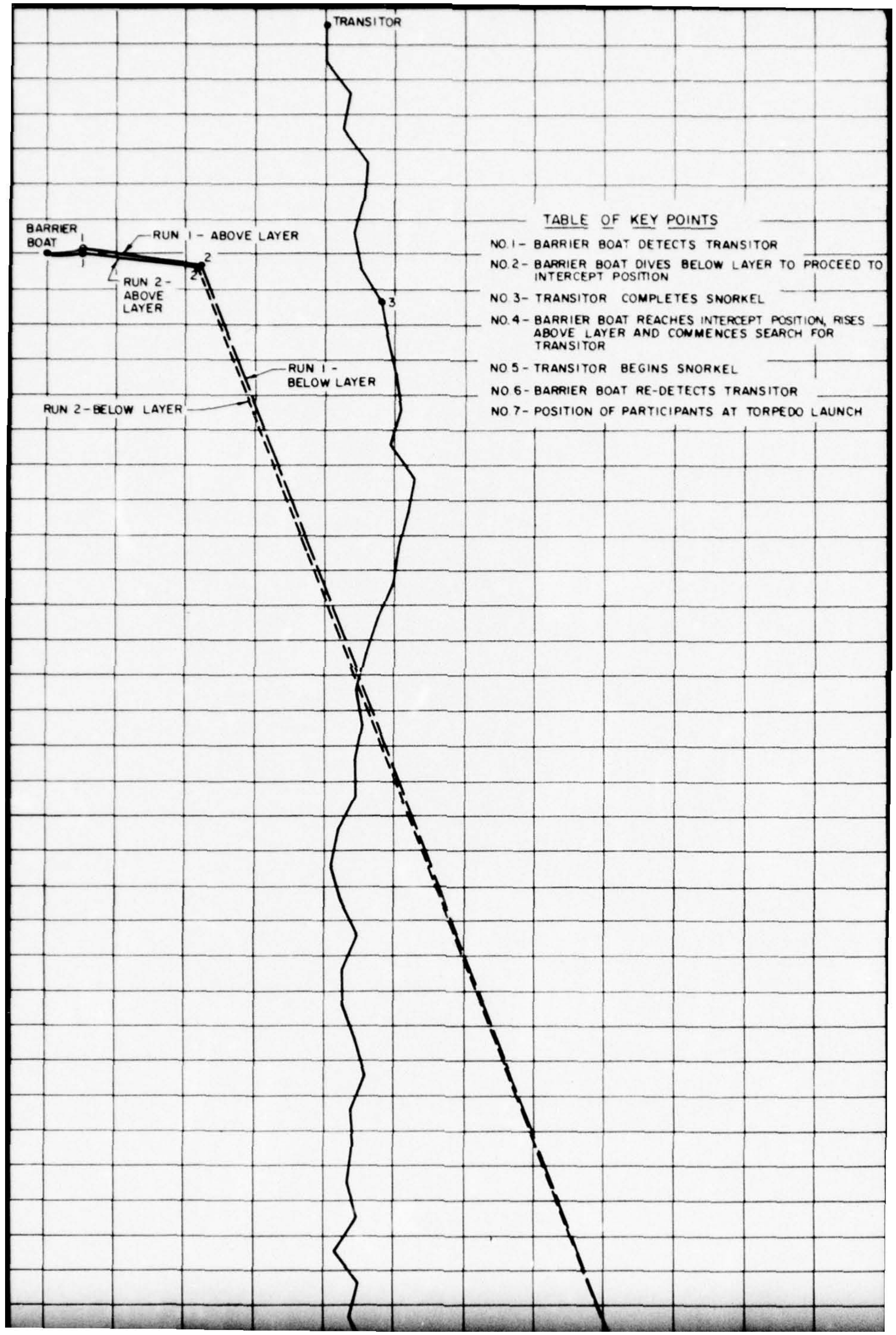
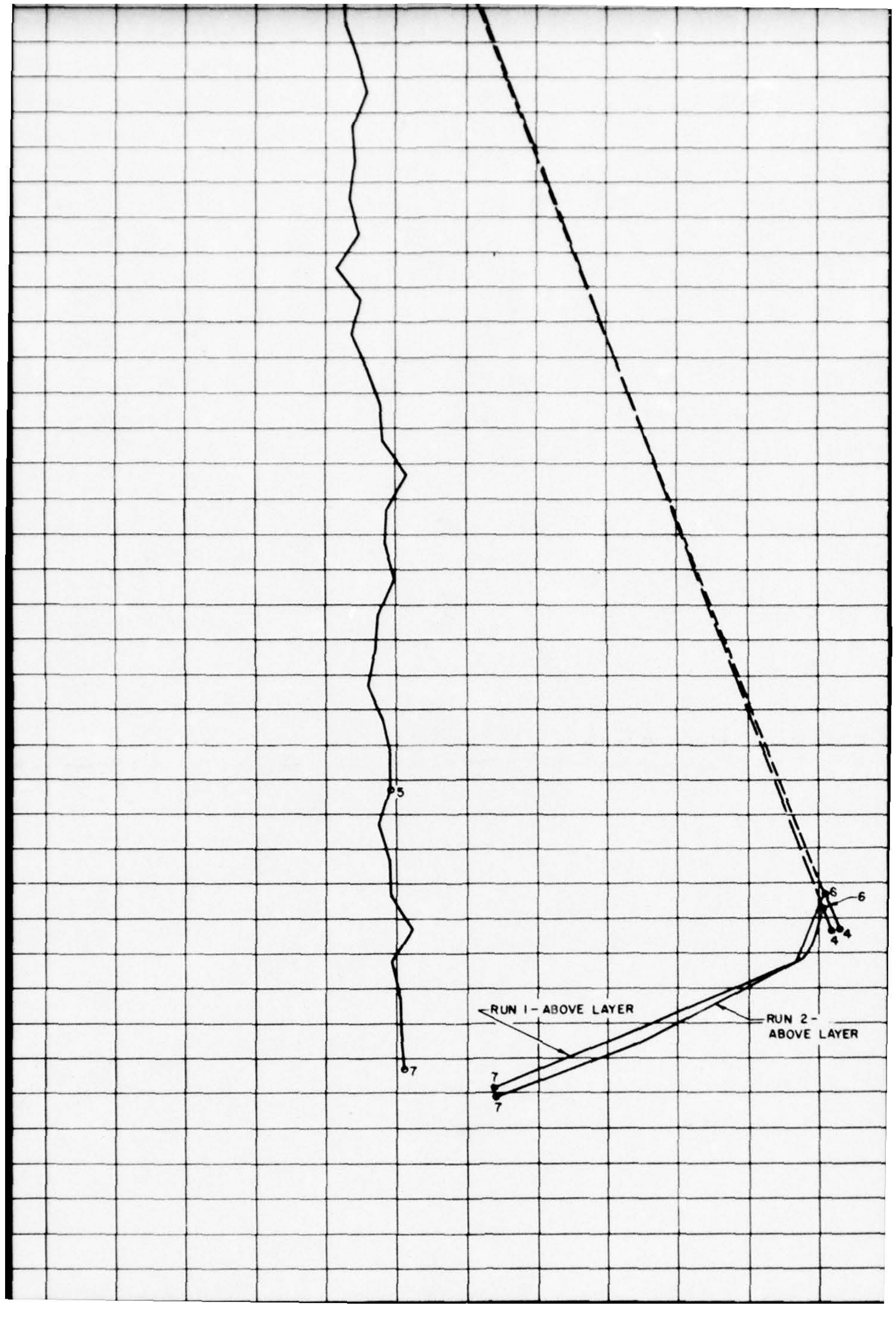
5. SAMPLE RESULTS

The performance description of the subsystems employed in the Forward Area Patrol Mission is statistical in nature. The statistical distribution of the performance of each of these subsystems has been accounted for in the simulation at the subsystem level, by random sampling from the appropriate distribution. To demonstrate the effect of these distributions upon decisions and upon the ultimate outcome of the engagement, a particular geometry of encounter was chosen. The participants were each diesel-electric submarines. The barrier submarine possesses the following subsystems in this example: Detection - AN/BQR-2 (DIMUS); Localization - AN/BQR-2 (DIMUS)(Bearing), AN/BQG-4 (Range and Bearing); Classification - AN/BQH-2C; Weapon - MK-48 Torpedo. The transitor submarine possesses the following subsystems in this example: Detection - AN/BQR-2B; Localization - AN/BQR-2B (Bearing). By this choice of subsystems, the Barrier Submarine is given a detection superiority. The transitor is initially snorkeling, on a base course parallel to the Y-axis in Figure 25. To disguise this course he makes turns every 5 minutes. These turns are randomly chosen between $\pm$ 20^{o} of his base course. The model was exercised three times. Each time a different random sample of the performance of each subsystem was chosen.

The results of the three runs are somewhat dissimilar. In the first two runs, the Barrier Ship detected the transitor, tracked him until the Barrier Ship felt he had a good estimate of the transitor's base course, computed an intercept position based on the estimated length of time before the transitor would next snorkel, intercepted, and launched a weapon. The kill probability for the first run was 0.941; the kill probability for the second run was 0.938. Both of these runs are displayed in Figure 25. In the third run, the Barrier Ship failed to reacquire the target upon reaching the intercept position. The transitor


TRANSITOR
BARRIER BOAT
RUN 1 - ABOVE LAYER
RUN 2 - ABOVE LAYER
RUN 1 - BELOW LAYER
RUN 2 - BELOW LAYER
1
2
3
TABLE OF KEY POINTS
NO. 1 - BARRIER BOAT DETECTS TRANSITOR
NO. 2 - BARRIER BOAT DIVES BELOW LAYER TO PROCEED TO INTERCEPT POSITION
NO. 3 - TRANSITOR COMPLETES SNORKEL
NO. 4 - BARRIER BOAT REACHES INTERCEPT POSITION, RISES ABOVE LAYER AND COMMENCES SEARCH FOR TRANSITOR
NO. 5 - TRANSITOR BEGINS SNORKEL
NO. 6 - BARRIER BOAT RE-DETECTS TRANSITOR
NO. 7 - POSITION OF PARTICIPANTS AT TORPEDO LAUNCH



RUN 1 - ABOVE LAYER
RUN 2 - ABOVE LAYER

thus escaped, and the kill probability is 0.0, as no weapon was launched.

Three runs are, of course, insufficient to give a complete measure of the effectiveness of the subsystems employed, but the effect of the statistical distribution of subsystem performance is clearly indicated.

It is now necessary to mention some peculiar aspects of the two runs illustrated in Fig. 25.

First, it will be observed that the Barrier Submarine does not snorkel throughout the encounter. This is because it is assumed that his reserves are sufficient to sustain him without snorkeling. In the absence of a contact the barrier ship would snorkel normally.

Second, it is noted that the ambush position is some distance from the base course of the transitor. This testifies to the success of the transitor in disguising his true course. It also suggests that the tactics used by the Barrier Ship to decipher the transitor's base course require some improvement, if not in real life, then at least in the model.

The last position for each ship shown in the diagram is that at weapon launch. From that point, the torpedo model Choice IIB completes the simulation, but does not now permit any recovery of the participant's positions as a function of time.

One point peculiar to both runs should be mentioned. The Barrier Ship redetected the transitor after reaching the intercept position and attempted to close with the transitor. Due to a discrepancy in the current model, the Barrier Ship increased his speed to such a point that the ensuing increase in self-noise prevented his obtaining any range data for a short time. At close range, and prior to detection by the

transitor, the Barrier Ship was able to obtain range data, establish a fire control track, and launch his weapon.

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6. IMPROVEMENT AND EXTENSION OF PRESENT SIMULATION MODEL

The two-submarine simulation model described in this Technical Memorandum is designed to be both a model of the Forward Area Patrol Mission and the initial phase of a multi-participant ASW Combat Simulation Model. The purpose of this chapter is to discuss means by which the current model can be made to simulate more realistically the Forward Area Patrol Mission and to point out the problems which must be solved before a multi-participant model can be constructed.

The present model can more realistically simulate the performance of each participant in ASW Combat by removing the deficiencies in each of the major areas:

1. Subsystem Performance,
2. Weapon Performance,
3. Information and Noise,
4. Assessment, Decision, and Action Processes, and
5. Vehicular Motion.

The deficiencies stem partially from insufficient information, and partially from time allowed for construction of the current model.

6.1 SUBSYSTEM PERFORMANCE

The most critical deficiencies in the simulation are in subsystem and weapon performance. This is true from the point of view of both the Forward Area Patrol Mission Simulation and the general multi-participant simulation.

Serious deficiencies exist in all categories of sonar subsystem performance. The simulation of passive sonar detection of a single contact for the dynamic situation is believed to be rather accurate. However, the technique lacks experimental

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validation. At present, the effect of multiple contacts on passive detection is not accurately known. The same is true for active sonar detection. The effect of mutual interference on active sonar detection is not accurately known.

The deficiencies in the simulation of existing localization subsystems result primarily from a paucity of experimental data of sufficient quality. Theoretical error analyses exist for many localization subsystems; however, these analyses do not consider all of the factors involved in subsystem performance. For example, the effect of own ship motion is almost always neglected. Furthermore, these analyses consider only one contact even though the performance of the localization subsystem in the presence of multiple contacts and mutual interference is a matter of extreme importance. Localization subsystems can be accurately simulated only after more and better performance data has been obtained and analyzed.

The classification problem requires a large amount of study before it can be accurately simulated.

The final major simulation deficiencies in the area of subsystem performance involve the fire control and tracking subsystems. In the present simulation, the tracking problem is treated by a least squares linear fit to position estimates of the contact provided by the range and bearing subsystem and by assuming perfect knowledge of own ship position. To be realistic, the model should be capable of accurately simulating the performance of automatic trackers, fire control computers, and plotting parties. Time limitations prevented an attempt to do this for the present model. If adequate experimental data is available, these simulations will be included in the general model.

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6.2 WEAPON PERFORMANCE

The present computer model relies on the Choice IIB torpedo model to simulate weapon performance. This torpedo model was developed by Ordnance Research Laboratory at Penn State for use in the design of the MK-48 torpedo. Though useful as a design tool, Choice IIB is too inflexible to be satisfactory as the torpedo simulation for the computer model for the following reasons:

1) Choice IIB models only the MK-48 torpedo while in reality each ship may possess a variety of torpedoes.

2) Choice IIB permits the interaction of only two ships - one a firing ship, the other a target ship - while in reality, each ship could play both roles, simultaneously.

3) Choice IIB permits each ship very limited interrogation of the model once the weapon has been launched, thus making decisions on unrealistic information.

4) Choice IIB simulates the MK-48 in conjunction with the PUFFS sonar system, when in reality, the MK-48 or any torpedo can be used in conjunction with various sonars.

To serve the ASW Combat Simulation Model, a torpedo simulation must be developed to satisfy the following requirements:

1) The simulation must be of a modular design. To model different torpedoes should merely require replacing component subprograms.

2) The simulation must permit the torpedo to become a participant in the model with time-stepped motion, command and control function, etc.

3) Each ship should be able to launch a torpedo while himself under attack.

4) The simulation must give each ship the same ability to interrogate the model both before and after launch of weapon.

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5) The simulation must be compatible with any weapon system of any ship.

Since the Forward Area Patrol Simulation model required the simulation of torpedo performance only, the problem of simulating the performance of other weapons was not addressed. It seems reasonable to assume that the performance of all required weapons can be adequately simulated provided adequate knowledge of this performance is available.

6.3 THE MEDIUM AND INFORMATION FLOW

Insufficient target strength data necessitated the assumption of a 15 dB target strength. More and better data is required to correct this deficiency.

Inaccuracies in the simulation of both radiated noise and self-noise also resulted from insufficient experimental data. All noise levels simulated in the present model are based on experimental data; but, in general, only a few data points are available. Thus, interpolation inaccuracies are introduced. Furthermore, the experimental data is such that isotropic noise must be assumed. In fact, noise is non-isotropic and this should be accounted for in the simulation. The simulation of reverberation must be included in future improvements of the model.

Propagation loss for a particular oceanographic condition and for each receiving sensor is stored as a table of source depth, receiver depth, and horizontal range between source and receiver. Currently, only three combinations of source and receiver depths should be included. Propagation loss curves for other oceanographic conditions should also be included if oceanographic conditions are expected to change during the course of the combat.

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In reality, propagation loss is a function of time, due to the rapid, local variation of oceanographic microstructure, as well as to the longer term, general variation of oceanographic macrostructure. A technique of including propagation loss as a function of time should be included in the simulation.

A more accurate technique of computing propagation loss would increase the accuracy of the simulation.

6.4 ASSESSMENT, DECISION, AND ACTION PROCESSES

To better simulate the assessment and decision processes effected by the decision maker, it is necessary to determine in more detail what criteria are used by the decision maker to formulate action. A more detailed description of tactical doctrine, and a complete idea of the role of knowledge and experience are both necessary to a realistic simulation of the command and control function.

In addition to these areas of human judgment, a knowledge of how battery level is a function of ship activity, and the length of time between decision and action for each action are also needed.

6.5 VEHICULAR MOTION

The current model permits a participant three possible types of motion:

1. Straight line, constant speed;
2. Circular course, constant speed;
3. Straight line, constant acceleration.

There are three dificiencies in this description of motion:

1. Acceleration is constant.
2. The equations of motion are integrated over a complete time step.

3. Only three degrees of freedom are allowed each participant.

A time-dependent acceleration is required to accurately simulate both linear acceleration and turning motion. If the appropriate accelerations were available, the command and control simulation for each participant would specify the new course desired and rudder angle, the new depth desired and rate of descent, or the new speed desired, and the simulation could be programmed to accurately simulate the resulting motion.

The finite time increment technique requires that the change in position of each participant occuring during the time step be evaluated at the end of the time step. There is no requirement that the equations of motion be integrated over the entire time step. Thus, the accuracy of motion simulation can be increased by allowing velocity changes to occur during a time step. This can be accomplished without difficulty. It was felt, however, that the absence of a time-dependent acceleration made such a feature superfluous.

The third motion deficiency is the restriction of each participant to three degrees of freedom. This restriction implies that each participant is a point mass while in reality each is a rigid body. To be realistic each participant should be allowed six degrees of freedom. This would permit the simulation of roll, pitch, and yaw effects. These quantities affect the performance of sonar sensors and own ship motion sensors. The six degrees of freedom problem can be handled in the simulation if all forces and torques acting on each participant are known.

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APPENDIX
FLOW CHART DESCRIPTION OF FORWARD AREA PATROL SIMULATION MODEL

The purpose of this appendix is to provide detailed information on each routine in the Forward Area Patrol Simulation Model. The theory upon which the routines are based is contained in the body of the report.

This appendix is conveniently divided into four parts, each part describing a major section of the simulation model. The four parts are CONTOL (Control and I/O Routine), POSIT (Position Routine), SUBSYS (Routines associated with Subsystems), and TACTIC (Routines associated with command decisions). The format for each part is the same. Each separate routine is identified by a brief description of its purpose. A description of the input, output and internal variables follows. The documentation of each routine concludes with a flow chart of the routine.

The torpedo model used in the Forward Area Patrol Simulation is described in separate documents[1,2], and a description will not be included in this report.

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[1]Greenstone, R., and J. W. McCutcheon, "Choice, A Probabilistic Model of an Advanced Torpedo," Tech. Memo. TM 412.2711-71, 18 May 1966, (Contract NOw65-0123-d).

[2]Greenstone, R., and J. J. Tully, "The Effect of Torpedo Radiated Noise on the MK48 MOD 0 Torpedo Weapon System," Part 5, Tech. Memo TM 412.2711-67, 6 May 1966, (Contract NOw65-0123-d).

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A.1 CONTOL

PURPOSE: This is the driver routine for the simulation model. The routines POSIT, SUBSYS, and TACTIC are called in that order by the driver routine at each time step.

In addition to being the driver routine CONTOL is the only input and principal output routine. The input and output roles of CONTOL will be considered in detail in this section.

Under the description of input, each card is labeled with the variables, and a definition is included for each variable. A sample of the labeled input as printed by the program is included after all input variables have been defined.

In the description of output, each column heading is defined, and a copy of sample output included for reference.

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INPUT

FORMATS:	INTEGER	(16I5)
	FLOATING	(4E20.10)
	LABELS	[8(A6,4X)]
	CARD IMAGE	(13A6,A2)

READ - (INTEGER) - NBOAT, [ITYPE (I), I=1, NBOAT]

NBOAT - Number of boats participating in model=2

ITYPE - Defines MISSION for each boat

0 = Barrier Boat

1 = Penetrator

(3 numbers) (1 card)

READ - (INTEGER) - IPRNT1, IPRNT2, IPRNT3, IPRNT4, IPRNT5, IPRNT6, IPRNT7

IPRNT1 - Tag for printing positions of both ships

IPRNT2 - Tag for printing subsystem values of Barrier Ship

IPRNT3 - Tag for printing subsystem values of Penetrator Ship

IPRNT4 - Tag for printing tracking information of Barrier Ship

IPRNT5 - Tag for printing fire control information of Barrier Ship

IPRNT6 - Tag for plotting information to be placed on Fastrand

IPRNT7 - Tag for PRINT1 call at every time step

Prints all pertinent information for all options:

0 = no

1 = yes

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IF PLOT OPTION IS SELECTED, THE FOLLOWING READS ARE NOW NECESSARY.

READ - (LABELS) - [LABVER(I), I=1, 11]

LABVER - Vertical labels for plot (11 labels)(2 cards)

READ - (LABELS) - [LABHOR(I), I=1, 21]

LABHOR - Horizontal labels (21 labels)(3 cards)

READ - (CARD IMAGE) - 2 cards to identify plot

READ - (LABELS) - Master, Name

Master - Master Name for Fastrand file

Name - Version (or subname) for Fastrand file

READ - (FLOATING) - XMINP, XMAXP, YMINP, YMAXP

XMINP - Minimum value of X for plot, X-direction is vertical, minimum at top.

XMAXP - Maximum value of X for plot, X-direction is vertical, maximum at bottom.

YMINP - Minimum value of Y for plot, Y-direction is horizontal, minimum at left.

YMAXP - Maximum value of Y for plot, Y-direction is horizontal, maximum at right.

READ - (INTEGER) - INCP

INCP - Printing and drum tag for number of time steps to be printed and read out to drum (e.g., INCP=5 means every fifth time step will be printed)

READ - (INTEGER) - [KEY (I), I=1, 7]

KEY - Random number generator key for probability of detection for Barrier Boat (7 numbers) (one card)

KEY1 - Random number generator key for probability of detection for Penetrator Boat (7 numbers) (one card)

READ - (INTEGER) - [JEY (I), I=1, 7]

JEY - Random number generator key for random ZIG-ZAG course for Penetrator (7 numbers) (one card)

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READ - (FLOATING) - [HEY (I), I=1, 7]

HEY - Random number generator key for normal distribution curves used in SUBSYS. (7 numbers) (two cards)

READ - (FLOATING) - TO, DELT

TO - Initial value of time variable (min)

DELT - Increment for time step (min)

READ - (FLOATING) - XMAX, YMAX, ZMAX

XMAX - Value of X-coordinate which determines barrier boundaries (yds)

YMAX - Value of Y-coordinate which determines barrier boundaries (yds)

ZMAX - Maximum depth allowed under any circumstances (negative) (yds)

READ - (INTEGER) - [NSYSTM (I), I=1, 5]

NSYSTM - Array of indexes for output which defines which system is being used for this run for the following subscripts

NSYSTM (1) = Barrier Detection Index
NSYSTM (2) = Barrier Passive Ranging System Index
NSYSTM (3) = Barrier Passive Bearing System Index
NSYSTM (4) = Barrier Active Ranging System Index
NSYSTM (5) = Barrier Classification System Index

For all indexes:

1 = BQS 4	MODIFIED	ACTIVE
2 = BQS 4		ACTIVE
3 = BQR 2B		PASSIVE
4 = ROVER		PASSIVE
5 = PUFFS		
6 = BQR 2 (DIMUS)		
7 = BQH 2C CLASSIFIER		

(5 numbers) (one card)

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READ - (INTEGER) - ISYSTT, ISYSRR

ISYSTT - Flag for tracking system bearing equipment

ISYSRR - Flag for tracking system ranging equipment

1 = BQS 4	MODIFIED	ACTIVE
2 = BQS 4		ACTIVE
3 = BQR 2B		PASSIVE
4 = ROVER		PASSIVE
5 = PUFFS		
6 = BQR 2 (DIMUS)		
7 = BQH 2C CLASSIFIER		

READ - (FLOATING) - [DETLM (I), I=1, 2], ATTENP (1)

DETLM - Detection thresholds (dB)

ATTENP - The absorption coefficient used in the Knudsen depth correction (dB/Yard)

READ - (INTEGER) - ISEAS

ISEAS - Sea State number

READ - (FLOATING) - [[F(I,J), DF(I,J), DI(I,J), J=7], I=1, 2]

F - Center frequency for each system of each boat (Hz)

DF - Bandwidth for each system of each boat (Hz)

DI - Directivity Index for each system of each boat (dB)

Note: 2 sets of 7 cards each, 3 numbers per card

READ - (FLOATING) - XMIN, YMIN, ZMIN

XMIN - Value of X-coordinate which determines barrier boundaries (yds)

YMIN - Value of Y-coordinate which determines barrier boundaries (yds)

ZMIN - Value of Z-coordinate which determines barrier boundaries (yds)
(3 numbers, 1 card)

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READ - (FLOATING) - [BLIND(1,I), BLIND(2,I), I=1, NBOAT]

BLIND - For each boat, blind spot definition relative to ships headings (smallest value first)

Note: 2 cards each with 2 numbers

READ - (INTEGER) - [NPASSD(I), I=1, 2]

NPASSD - Number of information points for sliding average to be used in passive detection for each boat (2 numbers) (one card)

READ - (INTEGER) - [MOTION(I), I=1, 2]

MOTION - For each boat an index defining type of motion:

1 = Straight line path, constant velocity
2 = Straight line path, constant acceleration
3 = Circular path, constant speed
(2 numbers) (one card)

READ - (INTEGER) - [IKIND(I), I=1, 2]

IKIND - Kind of boat:

0 = Nuclear
1 = Diesel-Electric
(2 numbers) (1 card)

READ - (FLOATING) - STIME

STIME - Stop Time, whenever time reaches this, value program stops (min)

READ - (INTEGER) - [ITACT(I), I=1, 2]

ITACT - Defines current tactic employed by each boat

FOR BOAT NO. 1:

1 = No detection has occurred
2 = Gather data on other boat
3 = Contact Lost-Patrol
4 = Contact Lost-Chase
5 = Fire Weapon
6 = Ambush
7 = Tail-Chase
8 = Evade
9 = Close and Attack

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FOR BOAT NO. 2:

1 = No detection has occured

2 = Evade

(2 numbers) (1 card)

READ - (INTEGER) - [ISNORK(I), I=1, NBOAT]

ISNORK - Defines snorkeling status of each boat:

0 = Not snorkeling

1 = Snorkeling

(2 numbers, 1 card)

READ - (FLOATING) - ESCAPE, TTURN

ESCAPE - The distance from the boundary at which the Penetrator has definitely escaped the Barrier Boat (yds)

TTURN - Time for Penetrator to execute a course change (min)

READ - (FLOATING) - [EDR(I,J,K), K=1, 2; J=1, 2; I=1, 2]

EDR - Set of Estimates of Detection Range in the absence of any information (yds)

For each boat, set consists of 2 cards, 2 numbers.

On each - The order of data is non-snorkeling estimate then snorkeling estimate on each card.

(8 numbers) (4 cards)

READ - (FLOATING) - [EWR(I,J), J=1, 2; I=1, 2]

EWR - Set of Estimates of Weapon Range (yds)

For each boat, set consists of 1 card and 2 numbers; order is:

IBoat's estimate of JBoat's Weapon Range

(4 numbers) (2 cards)

READ - (FLOATING) - [ESP(I,J), J=1, 2; I=1, 2]

ESP - Set of Estimates of Speed in the absence of all information (kts)

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For each boat, set consists of 1 card with 2 numbers; order is:
IBoat's estimate of JBoat's speed
(4 numbers) (2 cards)

READ - (FLOATING) - [EDR1(I,J), J=1, 2; I=1, 2]

EDR1 - Set of Estimates of Detection Range for use in time to fire determination (yds)

For each boat, set consists of 1 card with 2 numbers; order is:
IBoat's estimate of JBoat's detection range
(4 numbers) (2 cards)

READ - (FLOATING) - [EWR1(I,J), J=1, 2; I=1, 2]

EWR1 - Set of Estimates of Weapon Range for use in time to fire determination (yds)

For each boat, set consists of 1 card, 2 numbers; order is:
IBoat's estimate of JBoat's Weapon range
(4 numbers) (2 cards)

READ - (FLOATING) - [ZT(J,I), J=1, 9; I=1, 2]

ZT - Normal depth of each boat during each tactical situation (negative) (yds)

For each boat, set of 9 numbers, (3 cards), (4 numbers per first 2 cards, 1 number 3rd card)
(18 numbers) (6 cards)

READ - (FLOATING) - [ZS(I), I=1, 2]

ZS - The depth at which each boat snorkels (negative) (yds), (2 numbers) (1 card)

READ - (FLOATING) - [ZLIM(J,I), J=1, 2; I=1, 2]

ZLIM - For each boat, a two component vector which defines the maximum and minimum operating depth, (max value first) (negative) (yds)
(4 numbers) (2 cards)

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READ - (FLOATING) - [XMAN(I), I=1, 2]

XMAN - Minimum and maximum values of X inside of which Boat 1 must maneuver (small value first) (yds) (2 numbers)

READ - (FLOATING) - [YMAN(I), I=1, 2]

YMAN - Minimum and maximum value of Y inside of which Boat 1 must maneuver (small value first) (yds) (2 numbers)

READ - (FLOATING) - [WRMAX(I), I=1, 2]

WRMAX - Maximum range of each boat's weapons (yds) (2 numbers)

READ - (FLOATING) - [XPAT(I), I=1, 2]

XPAT - X coordinate of minimum and maximum patrol points for Boat No. 1 (small value first) (yds) (2 numbers)

READ - (FLOATING) - [CT(J,I), J=1, 9; I=1, 2]

CT - Set of normal speeds during tactical situations (kts)

For each boat, set consists of 9 numbers, 3 cards, (4 numbers each for first 2 cards, 3rd card, 1 number) (18 numbers) (6 cards)

READ - (FLOATING)- [CS(J,I), J=1, 9; I=1, 2]

CS - Set of speeds for each boat during each tactical situation while snorkeling (kts)

For each boat, set consists of 9 numbers, 3 cards (4 numbers each, first 2 cards, 3rd card, 1 number) (18 numbers) (6 cards)

READ - (FLOATING) - [CMIN(I), I=1, 2]

CMIN - For each boat minimum speed required to maintain steerage (kts) (2 numbers)

READ - (FLOATING) - [CMAX(I), I=1, 2]

CMAX - For each boat maximum speed (kts) (2 numbers)

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READE - (FLOATING) - [PHIO2(I), I=1, 2]

PHIO2 - Basic course of IBOAT (degrees) (2 numbers)

READ - (FLOATING) - [RFIRE(I), I=1, 2]

RFIRE - Maximum firing range of each boat (yds) (2 numbers)

READ - (FLOATING) - [TDLY(J,I), J=1, 9; I=1, 2]

TDLY - For each boat a vector which specifies a set of delay times required to react to each tactical situation change (min)

For each boat, set consists of (9 numbers, 3 cards) (4 numbers each first 2 cards, 3rd card, 1 number) (18 numbers) (6 cards)

READ - (FLOATING) - [TSS(I), I=1, 2]

TSS - For each boat, time to start next snorkel period (min) (2 numbers)

READ - (FLOATING) - [TCS(I), I=1, 2]

TCS - For each boat, time to stop next snorkel period (min) (2 numbers)

READ - (FLOATING) - [TLSNK(I), I=1, 2]

TLSNK - For each boat, time that boat completed last snorkel (min) (2 numbers)

READ - (FLOATING) - [SNBC(J,I), J=1, 9; I=1, 2]

SNBC - For each boat, a fraction representing the battery power level requiring snorkeling during tactical situations

For each boat, set consists of 9 numbers, 3 cards (4 numbers each, first 2 cards; third card, 1 number) (18 numbers) (6 cards)

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READ - (FLOATING) - [ETS(I), I=1, 2]

ETS - Estimate of snorkel frequency (min)
(2 numbers)

READ - (FLOATING) - [BSO(J,I), J=1, 7; RO(1,I), RO(2,I), RO(3,I), I=1, 2]

BSO - For each boat, a seven component vector which contains the motion parameters at time TO

BSO(1,NBOAT) = Horizontal linear speed (kts)
BSO(2,NBOAT) = Heading (degrees)
BSO(3,NBOAT) = Horizontal circular speed (kts)
BSO(4,NBOAT) = Radius of circle of motion (yds)
BSO(5,NBOAT) = X-coordinate of center of circle (yds)
BSO(6,NBOAT) = Y-coordinate of center of circle (yds)
BSO(7,NBOAT) = Horizontal linear acceleration (kts/min)

RO - For each boat, a three component vector which defines the initial positions (X,Y,Z) respectively (yds)

For each boat, set consists of 7 motion parameters, then
3 position parameters
(1st card - 4 numbers, 2nd card - 3 numbers,
3rd card - 3 numbers)
(20 numbers) (6 cards)

UNCLASSIFIED

SAMPLE INPUT DATA

```
BARRIER/PENETRATOR     RUN 040                DATE  120567  PAGE     2

                    BARRIER PENETRATOR MODEL

               NUMBER OF BOATS PARTICIPATING IN MODEL
                                2

TC=      .00     TIME INCRE.=     1.00     STOP TIME =  400.00

      XMAX= 50000.00      YMAX=100000.00      ZMAX= -2000.00

      XMIN=        .00    YMIN=        .00    ZMIN=        .00

                 BOUNDARY SPECIFICATIONS FOR PLOT

             XMAXP=          .00     YMAXP=          .00

             XMINP=          .00     YMINP=          .00

                        SEA STATE NUMBER
                                2

                           **********

                  RANDOM NUMBER GENERATOR KEYS

              PROBIBILITY OF DETECTION FOR BARRIER BOAT
   7          6          5          4          3          2          1

             PROBIBILITY OF DETECTION FOR PENETRATOR BOAT
   4          2          3          2          5          4          1

               RANDOM ZIG - ZAG COURSE FOR PENETRATOR
   3          6          1          3          8          7          2

               NORMAL DISTRIBUTION CURVES USED IN SUBSYS
 2.00       8.00       9.00       3.00       7.00       5.00       6.00

                           **********
```


UNCLASSIFIED

INPUT PARAMETERS FOR BARRIER BOAT

DIESEL ELECTRIC SUBMARINE
NOT SNORKELING
DEPTH AT WHICH BOAT SNORKELS
-10.00

SPEED OF SNORKELING BOAT DURING TACTICAL SITUATION I

1	2	3	4	5	6	7	8	9
3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00

TIME FOR BOAT TO START NEXT SNORKEL PERIOD
60.00

TIME FOR BOAT TO STOP NEXT SNORKEL PERIOD
65.00

TIME BOAT COMPLETED LAST SNORKEL
-5.00

A 15

FRACTION OF BATTERY POWER LEVEL REQUIRING SNORKELING DURING TACTICAL SITUATION I

1	2	3	4	5	6	7	8	9
.50	.50	.50	.50	.50	.50	.50	.50	.50

TYPE OF MOTION
CIRCULAR PATH, CONSTANT SPEED
HORIZONTAL CIRCULAR SPEED
3.00

RADIUS OF CIRCLE OF MOTION
2000.00

X-COORDINATE OF CENTER OF CIRCLE
25000.00

Y-COORDINATE OF CENTER OF CIRCLE
80000.00

CURRENT TACTIC EMPLOYED
1

BLIND SPOT OF SHIP IN DEGREES
FROM 165.0 TO 195.0

PASSIVE DETECTION AVERAGING LENGTH
12

BEARING (DEG.) = 90.00 SPEED = 3.00

X0= 25000.00 Y0= 78000.00 Z0= -30.00

ESTIMATE OF DETECTION RANGE

1	2	3	4	5	6	7	8
5000.00	5000.00	2000.00	2000.00	2000.00	2000.00	1500.00	1250.00

ESTIMATE OF WEAPON RANGE

1	2	3	4
30000.00	30000.00	20000.00	20000.00

ESTIMATE OF ENEMY'S SPEED

1	2
8.00	8.00

TIME TO FIRE DETERMINATION
ESTIMATE OF DETECTION RANGE

1	2	3	4
8000.00	5000.00	1760.00	1760.00

TIME TO FIRE DETERMINATION
ESTIMATE OF WEAPON RANGE

1	2	3	4
30000.00	25000.00	15000.00	20000.00

NORMAL DEPTH DURING TACTICAL SITUATION I

1	2	3	4	5	6	7	8	9
-30.00	-30.00	-30.00	-30.00	-30.00	-50.00	-30.00	-50.00	-30.00

OPERATING DEPTHS
MAXIMUM= 300.00 MINIMUM= .00

BOUNDARY INSIDE OF WHICH BOAT MUST MANEUVER
X-MIN= 5000.00 X-MAX= 45000.00 Y-MIN= 5000.00Y-MAX= 95000.00

MAXIMUM RANGE OF WEAPON
25000.00

X COORDINATES OF PATROL POINTS FOR BOAT
MAXIMUM= 40000.00 MINIMUM= 10000.00

NORMAL SPEED OF BOAT DURING TACTICAL SITUATION I

1	2	3	4	5	6	7	8	9
3.00	3.00	3.00	3.00	3.00	3.00	3.00	25.00	3.00

MINIMUM SPEED FOR BOAT TO MAINTAIN STEERAGE
3.00

MAXIMUM SPEED OF BOAT
25.00

MAXIMUM FIRING RANGE
10000.00

DELAY TIMES REQUIRED TO REACT TO TACTICAL SITUATIONS

1	2	3	4	5	6	7	8	9
.50	.50	.50	.50	.50	.50	.50	.50	.50

ESTIMATE OF ENEMY'S SNORKEL FREQUENCY
210.00

TRACKING SYSTEM EQUIPMENTS
BEARING= 5 RANGING= 5

DETECTION THRESHOLD
.10

CENTER FREQUENCIES FOR SYSTEMS
SYSTEM 1= 8000.00 SYSTEM 2= 6400.00 SYSTEM 3= 2000.00
SYSTEM 4= 2000.00 SYSTEM 5= 2000.00 SYSTEM 6= 2000.00
SYSTEM 7= 700.00 SYSTEM

FREQUENCY BANDWIDTHS FOR SYSTEMS
SYSTEM 1= 400.00 SYSTEM 2= 340.00 SYSTEM 3= 3000.00
SYSTEM 4= 3000.00 SYSTEM 5= 4900.00 SYSTEM 6= 3000.00
SYSTEM 7= 600.00 SYSTEM

DIRECTIVITY INDICES FOR SYSTEMS (NEGATIVE FOR RECEIVE)
SYSTEM 1= -21.70 SYSTEM 2= -21.50 SYSTEM 3= -13.00
SYSTEM 4= -9.00 SYSTEM 5= -9.00 SYSTEM 6= -11.00
SYSTEM 7= -13.00 SYSTEM

****

INPUT PARAMETERS FOR PENETRATOR BOAT

DIESEL ELECTRIC SUBMARINE
IS SNORKELING
DEPTH AT WHICH BOAT SNORKELS

CONFIDENTIAL

-10.00

SPEED OF SNORKELING BOAT DURING TACTICAL SITUATION I

1	2	3	4	5	6	7	8	9
6.00	6.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00

TIME FOR BOAT TO START NEXT SNORKEL PERIOD
250.00

TIME FOR BOAT TO STOP NEXT SNORKEL PERIOD
40.00

TIME BOAT COMPLETED LAST SNORKEL
-180.00

FRACTION OF BATTERY POWER LEVEL REQUIRING SNORKELING DURING TACTICAL SITUATION I

1	2	3	4	5	6	7	8	9
.50	.50	-.00	-.00	-.00	-.00	-.00	-.00	-.00

TYPE OF MOTION
STRAIGHT LINE PATH, CONSTANT VELOCITY
HORIZONTAL LINEAR ACCELERATION
.00

CURRENT TACTIC EMPLOYED
1

BLIND SPOT OF SHIP IN DEGREES
FROM 165.0 TO 195.0

PASSIVE DETECTION AVERAGING LENGTH
72

BEARING (DEG.) = 180.00 SPEED = 6.00

XO= 29000.00 YO= 84500.00 ZO= -10.00

CENTER FREQUENCIES FOR SYSTEMS
SYSTEM 1= .00 SYSTEM 2= .00 SYSTEM 3= 2000.00
SYSTEM 4= .00 SYSTEM 5= .00 SYSTEM 6= .00
SYSTEM 7= .00 SYSTEM

FREQUENCY BANDWIDTHS FOR SYSTEMS
SYSTEM 1= .00 SYSTEM 2= .00 SYSTEM 3= 3000.00
SYSTEM 4= .00 SYSTEM 5= .00 SYSTEM 6= .00
SYSTEM 7= .00 SYSTEM

DIRECTIVITY INDICES FOR SYSTEMS (NEGATIVE FOR RECEIVE)
SYSTEM 1= .00 SYSTEM 2= .00 SYSTEM 3= -13.00
SYSTEM 4= .00 SYSTEM 5= .00 SYSTEM 6= .00
SYSTEM 7= .00 SYSTEM

CONFIDENTIAL

DISTANCE FROM BOUNDARY DEFINING ESCAPE
10000.00

TIME TO EXECUTE COURSE CHANGE
5.00

ESTIMATE OF DETECTION RANGE

1	2	3	4	5	6	7	8
2000.00	2000.00	2000.00	2000.00	1500.00	1250.00	30000.00	30000.00

ESTIMATE OF WEAPON RANGE

1	2	3	4
30000.00	30000.00	20000.00	20000.00

ESTIMATE OF ENEMY'S SPEED

1	2
8.00	8.00

TIME TO FIRE DETERMINATION
ESTIMATE OF DETECTION RANGE

1	2	3	4
8000.00	5000.00	1760.00	1760.00

TIME TO FIRE DETERMINATION
ESTIMATE OF WEAPON RANGE

1	2	3	4
30000.00	25000.00	15000.00	20000.00

NORMAL DEPTH DURING TACTICAL SITUATION I

1	2	3	4	5	6	7	8	9
-30.00	-50.00	.00	.00	.00	.00	.00	.00	.00

OPERATING DEPTHS
MAXIMUM= 300.00 MINIMUM= .00

MAXIMUM RANGE OF WEAPON
25000.00

NORMAL SPEED OF BOAT DURING TACTICAL SITUATION I

1	2	3	4	5	6	7	8	9
6.00	22.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00

MINIMUM SPEED FOR BOAT TO MAINTAIN STEERAGE
3.00

MAXIMUM SPEED OF BOAT
22.00

BASIC COURSE OF PENETRATOR
180.00

MAXIMUM FIRING RANGE
10000.00

DELAY TIMES REQUIRED TO REACT TO TACTICAL SITUATIONS

1	2	3	4	5	6	7	8	9
.50	.50	-.00	-.00	-.00	-.00	-.00	-.00	-.00

****

ESTIMATE OF ENEMY'S SNORKEL FREQUENCY
210.00

DETECTION THRESHOLD
.10

TRACOR 6500 TRACOR LANE, AUSTIN, TEXAS 78721

OUTPUT

1. SHIP POSITIONS (For both Barrier Boat and Penetrator Boat:

TIME	=	Time (min)
HEADING	=	Angle from North to boat's axis (degrees)
SPEED	=	Speed of boat (kts)
(X,Y,Z)	=	Coordinates of boat in barrier coordinate system (yds)
RHO	=	True range between boats (yds)

2. SUBSYSTEM VALUES (BARRIER BOAT VALUES)

TIME	=	Time (min)
TACTIC	=	Tactical situation for Barrier Boat
SNORK	=	Flat to indicate if Barrier Boat is snorkeling (=1) or not (=0)
AVE S/N	=	The maximum average signal-to-noise ratio for the detection subsystem at the time (dB)
S/N	=	Signal-to-noise level computed at the time by the S to N routine as seen at the detection subsystem (dB)
PROB D	=	Probability of detection
D. BEARING*	=	Relative bearing reported by the AN/BQR-2(DIMUS)passive bearing subsystem (degrees)
D. B ERR	=	Error in the bearing reported by the DIMUS subsystem (degrees)
P. BEAR*	=	Relative bearing reported by PUFFS (AN/BQG-4) subsystem (degrees)
P.B ERR	=	Error in the bearing reported by PUFFS (degrees)

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* Negative value means signal too low for subsystem to provide information.

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P. RANGE* = Range reported by the PUFFS subsystem (yds)

P. R ERR = Error in range reported by PUFFS (yds)

3. SUBSYSTEM VALUES (PENETRATOR BOAT VALUES)

TIME = Time (min)

TACTIC = Tactical situation for Penetrator Boat

SNORK = Flag to indicate if Penetrator is snorkeling (=1) or not (=0)

AVE S/N = Maximum average signal-to-noise ratio for the detection subsystem at the time (dB)

S/N = Signal-to-noise ratio currently available to the detection subsystem of the Penetrator (dB)

PROB D = Probability of detection

BEARING* = Relative bearing reported by Penetrator's bearing subsystem (degrees)

BEAR ERR = Error in error reported by bearing subsystem (degrees)

RHO = Actual range between boats (yds)

4. SUBSYSTEM VALUES (Barrier Boat, Tracking Information)

TIME = Time (min)

X(EST.) = Current estimated X-coordinate of target on base course (yds)

Y(EST.) = Current estimated Y-coordinate of target on base course (yds)

SPEED (EST.)= Current estimate of target's speed along base course (kts)

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* Negative value indicates signal level too low for subsystems to provide information.

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DIST	=	Number of points stored in base course track
TRACKING FLAGS X,Y	=	Flags indicating that X or Y motion estimates satisfy (=1) criteria or don't (=0)
XVEL(EST)	=	Estimate of X-velocity of target (kts)
YVEL(EST)	=	Estimate of Y-velocity of target (kts)
SIGMA X	=	Standard deviation of X-data about least squares line (yds)
SIGMA Y	=	Standard deviation of Y-data about least squares line (yds)

SUBSYSTEM VALUES (Barrier Boat, Fire Control Information) (Same as TRACKING INFORMATION DEFINITIONS EXCEPT current course must be substituted for Base course)

SAMPLE OUTPUT DATA

CARRIER/PENETRATOR RUN 040 DATE 120567 PAGE 13

SHIP POSITIONS

	CARRIER BOAT						PENETRATOR BOAT					
TIME	HEADING	SPEED	X	Y	Z	HEADING	SPEED	X	Y	Z	RHO
0.	90.00	3.00	25000.00	78000.00	-30.00	180.00	6.00	29000.00	84500.00	-10.00	7630.00
1.	87.10	3.00	25101.31	78002.57	-30.00	180.00	6.00	29000.00	84297.30	-10.00	7404.29
2.	84.19	3.00	25202.35	78010.26	-30.00	180.00	6.00	29000.00	84094.61	-10.00	7172.26
3.	81.29	3.00	25302.88	78023.07	-30.00	180.00	6.00	29000.00	83891.91	-10.00	6936.28
4.	78.39	3.00	25402.62	78040.95	-30.00	180.00	6.00	29000.00	83689.21	-10.00	6696.57
5.	75.48	3.00	25501.34	78063.86	-30.00	160.00	6.00	29000.00	83486.51	-10.00	6453.36
6.	103.74	3.00	25599.45	78089.26	-30.00	160.00	6.00	29069.33	83296.04	-10.00	6257.04
7.	103.74	3.00	25697.90	78065.19	-30.00	160.00	6.00	29138.65	83105.57	-10.00	6102.80
8.	103.74	3.00	25796.35	78041.12	-30.00	160.00	6.00	29207.98	82915.09	-10.00	5949.36
9.	103.74	3.00	25894.80	78017.05	-30.00	160.00	6.00	29277.31	82724.62	-10.00	5796.78
10.	103.74	3.00	25993.25	77992.97	-30.00	185.00	6.00	29346.63	82534.15	-10.00	5645.12
11.	103.74	3.00	26091.70	77968.90	-30.00	185.00	6.00	29328.97	82332.22	-10.00	5433.09
12.	103.74	3.00	26190.14	77944.83	-30.00	185.00	6.00	29311.30	82130.29	-10.00	5221.08
13.	103.74	3.00	26288.59	77920.76	-30.00	185.00	6.00	29293.63	81928.37	-10.00	5009.11
14.	103.74	3.00	26387.04	77896.69	-30.00	185.00	6.00	29275.97	81726.44	-10.00	4797.18
15.	103.74	3.00	26485.49	77872.62	-30.00	160.00	6.00	29258.30	81524.52	-10.00	4585.29
16.	103.74	3.00	26583.94	77848.55	-30.00	160.00	6.00	29327.63	81334.04	-10.00	4435.82
17.	103.74	3.00	26682.39	77824.48	-30.00	160.00	6.00	29396.95	81143.57	-10.00	4287.80
18.	103.74	3.00	26780.84	77800.40	-30.00	160.00	6.00	29466.28	80953.10	-10.00	4141.39
19.	103.74	3.00	26879.29	77776.33	-30.00	160.00	6.00	29535.61	80762.62	-10.00	3996.75
20.	103.74	3.00	26977.74	77752.26	-30.00	183.00	6.00	29604.93	80572.15	-10.00	3854.08
21.	103.74	3.00	27076.18	77728.19	-30.00	183.00	6.00	29594.33	80369.73	-10.00	3649.49
22.	103.74	3.00	27174.63	77704.12	-30.00	183.00	6.00	29583.72	80167.31	-10.00	3445.43
23.	168.94	6.25	27273.08	77680.05	-50.00	183.00	6.00	29573.11	79964.89	-10.00	3242.01
24.	168.94	6.25	27313.55	77472.97	-50.00	183.00	6.00	29562.50	79762.47	-10.00	3209.30
25.	168.94	6.25	27354.02	77265.88	-50.00	189.00	6.00	29551.89	79560.05	-10.00	3177.08
26.	168.94	6.25	27394.49	77058.80	-50.00	189.00	6.00	29520.19	79359.85	-10.00	3132.63
27.	168.94	6.25	27434.96	76851.72	-50.00	189.00	6.00	29488.48	79159.64	-10.00	3089.25
28.	168.94	6.25	27475.43	76644.64	-50.00	189.00	6.00	29456.77	78959.44	-10.00	3046.97
29.	168.94	6.25	27515.90	76437.56	-50.00	189.00	6.00	29425.06	78759.24	-10.00	3005.84
30.	168.94	6.25	27556.37	76230.47	-50.00	174.00	6.00	29393.35	78559.04	-10.00	2965.92
31.	168.94	6.25	27596.84	76023.39	-50.00	174.00	6.00	29414.54	78357.45	-10.00	2958.35
32.	168.94	6.25	27637.31	75816.31	-50.00	174.00	6.00	29435.73	78155.86	-10.00	2950.90
33.	168.94	6.25	27677.78	75609.23	-50.00	174.00	6.00	29456.91	77954.28	-10.00	2943.56
34.	168.94	6.25	27718.25	75402.15	-50.00	174.00	6.00	29478.10	77752.69	-10.00	2936.35
35.	168.94	6.25	27758.72	75195.06	-50.00	162.00	6.00	29499.29	77551.10	-10.00	2929.25

SHIP POSITIONS

TIME	BARRIER BOAT HEADING	SPEED	X	Y	Z	PENETRATOR BOAT HEADING	SPEED	X	Y	Z	RHO
36.	168.94	6.25	27799.19	74987.98	-50.00	162.00	6.00	29561.92	77358.33	-10.00	2953.94
37.	168.94	6.25	27839.66	74780.90	-50.00	162.00	6.00	29624.56	77165.55	-10.00	2978.66
38.	168.94	6.25	27880.13	74573.82	-50.00	162.00	6.00	29687.20	76972.77	-10.00	3003.41
39.	168.94	6.25	27920.60	74366.74	-50.00	162.00	6.00	29749.84	76780.00	-10.00	3028.19
40.	168.94	6.25	27961.07	74159.65	-50.00	176.00	6.00	29812.47	76587.22	-30.00	3052.99
41.	168.94	6.25	28001.54	73952.57	-50.00	176.00	6.00	29826.61	76385.02	-30.00	3041.00
42.	168.94	6.25	28042.01	73745.49	-50.00	176.00	6.00	29840.75	76182.81	-30.00	3029.19
43.	168.94	6.25	28082.49	73538.41	-50.00	176.00	6.00	29854.89	75980.61	-30.00	3017.58
44.	168.94	6.25	28122.96	73331.33	-50.00	176.00	6.00	29869.03	75778.41	-30.00	3006.16
45.	168.94	6.25	28163.43	73124.24	-50.00	174.00	6.00	29883.17	75576.20	-30.00	2994.93
46.	168.94	6.25	28203.90	72917.16	-50.00	174.00	6.00	29904.36	75374.61	-30.00	2988.42
47.	168.94	6.25	28244.37	72710.08	-50.00	174.00	6.00	29925.55	75173.03	-30.00	2982.03
48.	168.94	6.25	28284.84	72503.00	-50.00	174.00	6.00	29946.73	74971.44	-30.00	2975.75
49.	168.94	6.25	28325.31	72295.92	-50.00	174.00	6.00	29967.92	74769.85	-30.00	2969.60
50.	168.94	6.25	28365.78	72088.83	-50.00	175.00	6.00	29989.11	74568.27	-30.00	2963.58
51.	168.94	6.25	28406.25	71881.75	-50.00	175.00	6.00	30006.77	74366.34	-30.00	2955.48
52.	168.94	6.25	28446.72	71674.67	-50.00	175.00	6.00	30024.44	74164.42	-30.00	2947.55
53.	168.94	6.25	28487.19	71467.59	-50.00	175.00	6.00	30042.11	73962.49	-30.00	2939.78
54.	168.94	6.25	28527.66	71260.51	-50.00	175.00	6.00	30059.77	73760.56	-30.00	2932.18
55.	168.94	6.25	28568.13	71053.42	-50.00	188.00	6.00	30077.44	73558.64	-30.00	2924.74
56.	168.94	6.25	28608.60	70846.34	-50.00	188.00	6.00	30049.23	73357.91	-30.00	2895.41
57.	168.94	6.25	28649.07	70639.26	-50.00	188.00	6.00	30021.02	73157.19	-30.00	2867.44
58.	168.94	6.25	28689.54	70432.18	-50.00	188.00	6.00	29992.81	72956.46	-30.00	2840.87
59.	168.94	6.25	28730.01	70225.10	-50.00	188.00	6.00	29964.60	72755.74	-30.00	2815.74
60.	168.94	6.25	28770.48	70018.01	-50.00	161.00	6.00	29936.39	72555.02	-30.00	2792.08
61.	168.94	6.25	28810.95	69810.93	-50.00	161.00	6.00	30002.38	72363.36	-30.00	2816.81
62.	168.94	6.25	28851.42	69603.85	-50.00	161.00	6.00	30068.37	72171.71	-30.00	2841.63
63.	168.94	6.25	28891.89	69396.77	-50.00	161.00	6.00	30134.36	71980.05	-30.00	2866.55
64.	168.94	6.25	28932.36	69189.68	-50.00	161.00	6.00	30200.36	71788.40	-30.00	2891.56
65.	168.94	6.25	28972.83	68982.60	-50.00	185.00	6.00	30266.35	71596.74	-30.00	2916.60
66.	168.94	6.25	29013.30	68775.52	-50.00	185.00	6.00	30248.68	71394.82	-30.00	2896.01
67.	168.94	6.25	29053.77	68568.44	-50.00	185.00	6.00	30231.02	71192.89	-30.00	2876.40
68.	168.94	6.25	29094.24	68361.36	-50.00	185.00	6.00	30213.35	70990.97	-30.00	2857.84
69.	168.94	6.25	29134.71	68154.27	-50.00	185.00	6.00	30195.68	70789.04	-30.00	2840.36
70.	168.94	6.25	29175.18	67947.19	-50.00	188.00	6.00	30178.02	70587.11	-30.00	2823.98
71.	168.94	6.25	29215.65	67740.11	-50.00	188.00	6.00	30149.81	70386.39	-30.00	2806.32

SHIP POSITIONS

	BARRIER BOAT						PENETRATOR BOAT						
TIME	HEADING	SPEED	X	Y	Z	HEADING	SPEED	X	Y	Z	RHO
72.	168.94	6.25	29256.12	67533.03	-50.00	188.00	6.00	30121.60	70185.67	-30.00	2790.26
73.	168.94	6.25	29296.59	67325.95	-50.00	188.00	6.00	30093.39	69984.94	-30.00	2775.81
74.	168.94	6.25	29337.06	67118.86	-50.00	188.00	6.00	30065.18	69784.22	-30.00	2763.01
75.	168.94	6.25	29377.53	66911.78	-50.00	184.00	6.00	30036.97	69583.49	-30.00	2751.89
76.	168.94	6.25	29418.00	66704.70	-50.00	184.00	6.00	30022.83	69381.29	-30.00	2744.07
77.	168.94	6.25	29458.47	66497.62	-50.00	184.00	6.00	30008.69	69179.08	-30.00	2737.33
78.	168.94	6.25	29498.94	66290.54	-50.00	184.00	6.00	29994.55	68976.88	-30.00	2731.68
79.	168.94	6.25	29539.41	66083.45	-50.00	184.00	6.00	29980.41	68774.67	-30.00	2727.11
80.	168.94	6.25	29579.88	65876.37	-50.00	192.00	6.00	29966.27	68572.47	-30.00	2723.65
81.	168.94	6.25	29620.35	65669.29	-50.00	192.00	6.00	29924.13	68374.20	-30.00	2721.92
82.	168.94	6.25	29660.82	65462.21	-50.00	192.00	6.00	29881.98	68175.93	-30.00	2722.72
83.	168.94	6.25	29701.29	65255.13	-50.00	192.00	6.00	29839.84	67977.67	-30.00	2726.06
84.	168.94	6.25	29741.76	65048.04	-50.00	192.00	6.00	29797.70	67779.40	-30.00	2731.93
85.	168.94	6.25	29782.23	64840.96	-50.00	187.00	6.00	29755.56	67581.13	-30.00	2740.30
86.	168.94	6.25	29822.70	64633.88	-50.00	187.00	6.00	29730.85	67379.94	-30.00	2747.60
87.	168.94	6.25	29863.18	64426.80	-50.00	187.00	6.00	29706.15	67178.76	-30.00	2756.43
88.	168.94	6.25	29903.65	64219.72	-50.00	187.00	6.00	29681.45	66977.57	-30.00	2766.79
89.	168.94	6.25	29944.12	64012.63	-50.00	187.00	6.00	29656.74	66776.38	-30.00	2778.65
90.	168.94	6.25	29984.59	63805.55	-50.00	190.00	6.00	29632.04	66575.20	-30.00	2791.99
91.	168.94	6.25	30025.06	63598.47	-50.00	190.00	6.00	29596.84	66375.58	-30.00	2809.93
92.	168.94	6.25	30065.53	63391.39	-50.00	190.00	6.00	29561.65	66175.96	-30.00	2829.79
93.	168.94	6.25	30106.00	63184.31	-50.00	190.00	6.00	29526.45	65976.34	-30.00	2851.55
94.	168.94	6.25	30146.47	62977.22	-50.00	190.00	6.00	29491.25	65776.72	-30.00	2875.15
95.	168.94	6.25	30186.94	62770.14	-50.00	176.00	6.00	29456.05	65577.10	-30.00	2900.56
96.	168.94	6.25	30227.41	62563.06	-50.00	176.00	6.00	29470.19	65374.90	-30.00	2912.01
97.	168.94	6.25	30267.88	62355.98	-50.00	176.00	6.00	29484.33	65172.70	-30.00	2923.67
98.	168.94	6.25	30308.35	62148.90	-50.00	176.00	6.00	29498.47	64970.49	-30.00	2935.53
99.	168.94	6.25	30348.82	61941.81	-50.00	176.00	6.00	29512.61	64768.29	-30.00	2947.58
100.	168.94	6.25	30389.29	61734.73	-50.00	186.00	6.00	29526.75	64566.08	-30.00	2959.82
101.	168.94	6.25	30429.76	61527.65	-50.00	186.00	6.00	29505.56	64364.50	-30.00	2983.60
102.	168.94	6.25	30470.23	61320.57	-50.00	186.00	6.00	29484.37	64162.91	-30.00	3008.46
103.	168.94	6.25	30510.70	61113.49	-50.00	186.00	6.00	29463.19	63961.32	-30.00	3034.38
104.	168.94	6.25	30551.17	60906.40	-50.00	186.00	6.00	29442.00	63759.73	-30.00	3061.33
105.	168.94	6.25	30591.64	60699.32	-50.00	179.00	6.00	29420.81	63558.15	-30.00	3089.29
106.	168.94	6.25	30632.11	60492.24	-50.00	179.00	6.00	29424.35	63355.48	-30.00	3107.54
107.	168.94	6.25	30672.58	60285.16	-50.00	179.00	6.00	29427.89	63152.81	-30.00	3126.13

SHIP POSITIONS

TIME	BARRIER BOAT HEADING	SPEED	X	Y	Z	PENETRATOR BOAT HEADING	SPEED	X	Y	Z	RHO
108.	168.94	6.25	30713.05	60078.08	-50.00	179.00	6.00	29431.42	62950.15	-30.00	3145.05
109.	168.94	6.25	30753.52	59870.99	-50.00	179.00	6.00	29434.96	62747.48	-30.00	3164.30
110.	168.94	6.25	30793.99	59663.91	-50.00	194.00	6.00	29438.50	62544.81	-30.00	3183.86
111.	168.94	6.25	30834.46	59456.83	-50.00	194.00	6.00	29389.46	62348.14	-30.00	3232.29
112.	168.94	6.25	30874.93	59249.75	-50.00	194.00	6.00	29340.42	62151.46	-30.00	3282.47
113.	168.94	6.25	30915.40	59042.67	-50.00	194.00	6.00	29291.39	61954.78	-30.00	3334.34
114.	168.94	6.25	30955.87	58835.58	-50.00	194.00	6.00	29242.35	61758.11	-30.00	3387.81
115.	168.94	6.25	30996.34	58628.50	-50.00	186.00	6.00	29193.31	61561.43	-30.00	3442.81
116.	168.94	6.25	31036.81	58421.42	-50.00	186.00	6.00	29172.13	61359.84	-30.00	3480.14
117.	168.94	6.25	31077.28	58214.34	-50.00	186.00	6.00	29150.94	61158.25	-30.00	3518.16
118.	168.94	6.25	31117.75	58007.26	-50.00	186.00	6.00	29129.75	60956.67	-30.00	3556.85
119.	168.94	6.25	31158.22	57800.17	-50.00	186.00	6.00	29108.56	60755.08	-30.00	3596.19
120.	168.94	6.25	31198.69	57593.09	-50.00	173.00	6.00	29087.38	60553.49	-30.00	3636.15
121.	168.94	6.25	31239.16	57386.01	-50.00	173.00	6.00	29112.08	60352.30	-30.00	3650.12
122.	168.94	6.25	31279.63	57178.93	-50.00	173.00	6.00	29136.78	60151.12	-30.00	3664.11
123.	168.94	6.25	31320.10	56971.85	-50.00	173.00	6.00	29161.48	59949.93	-30.00	3678.13
124.	168.94	6.25	31360.57	56764.76	-50.00	173.00	6.00	29186.19	59748.74	-30.00	3692.17
125.	168.94	6.25	31401.04	56557.68	-50.00	165.00	6.00	29210.89	59547.56	-30.00	3706.23
126.	168.94	6.25	31441.51	56350.60	-50.00	165.00	6.00	29263.35	59351.77	-30.00	3708.29
127.	168.94	6.25	31481.98	56143.52	-50.00	165.00	6.00	29315.81	59155.97	-30.00	3710.42
128.	168.94	6.25	31522.45	55936.43	-50.00	165.00	6.00	29368.28	58960.18	-30.00	3712.62
129.	168.94	6.25	31562.92	55729.35	-50.00	165.00	6.00	29420.74	58764.39	-30.00	3714.89
130.	168.94	6.25	31603.39	55522.27	-50.00	192.00	6.00	29473.20	58568.60	-30.00	3717.24
131.	168.94	6.25	31643.86	55315.19	-50.00	192.00	6.00	29431.06	58370.33	-30.00	3772.32
132.	168.94	6.25	31684.33	55108.11	-50.00	192.00	6.00	29388.91	58172.06	-30.00	3828.42
133.	168.94	6.25	31724.80	54901.02	-50.00	192.00	6.00	29346.77	57973.80	-30.00	3885.48
134.	168.94	6.25	31765.27	54693.94	-50.00	192.00	6.00	29304.63	57775.53	-30.00	3943.47
135.	168.94	6.25	31805.74	54486.86	-50.00	180.00	6.00	29262.48	57577.26	-30.00	4002.34
136.	168.94	6.25	31846.22	54279.78	-50.00	180.00	6.00	29262.48	57374.56	-30.00	4031.54
137.	168.94	6.25	31886.69	54072.70	-50.00	180.00	6.00	29262.48	57171.86	-30.00	4060.94
138.	168.94	6.25	31927.16	53865.61	-50.00	180.00	6.00	29262.48	56969.17	-30.00	4090.54
139.	168.94	6.25	31967.63	53658.53	-50.00	180.00	6.00	29262.48	56766.47	-30.00	4120.32
140.	168.94	6.25	32008.10	53451.45	-50.00	170.00	6.00	29262.48	56563.77	-30.00	4150.29
141.	168.94	6.25	32048.57	53244.37	-50.00	170.00	6.00	29297.68	56364.15	-30.00	4159.38
142.	168.94	6.25	32089.04	53037.29	-50.00	170.00	6.00	29332.88	56164.53	-30.00	4168.46
143.	168.94	6.25	32129.51	52830.20	-50.00	170.00	6.00	29368.08	55964.92	-30.00	4177.55

SHIP POSITIONS

	BARRIER BOAT						PENETRATOR BOAT					
TIME	HEADING	SPEED	X	Y	Z	HEADING	SPEED	X	Y	Z	RHO
144.	168.94	6.25	32169.98	52623.12	-50.00	170.00	6.00	29403.28	55765.30	-30.00	4186.63
145.	168.94	6.25	32210.45	52416.04	-50.00	172.00	6.00	29438.47	55565.68	-30.00	4195.72
146.	168.94	6.25	32250.92	52208.96	-50.00	172.00	6.00	29466.68	55364.95	-30.00	4208.59
147.	168.94	6.25	32291.39	52001.88	-50.00	172.00	6.00	29494.89	55164.23	-30.00	4221.47
148.	168.94	6.25	32331.86	51794.79	-50.00	172.00	6.00	29523.10	54963.50	-30.00	4234.36
149.	168.94	6.25	32372.33	51587.71	-50.00	172.00	6.00	29551.31	54762.78	-30.00	4247.25
150.	168.94	6.25	32412.80	51380.63	-50.00	192.00	6.00	29579.52	54562.05	-30.00	4260.15
151.	168.94	6.25	32453.27	51173.55	-50.00	192.00	6.00	29537.38	54363.78	-30.00	4322.04
152.	168.94	6.25	32493.74	50966.47	-50.00	192.00	6.00	29495.24	54165.52	-30.00	4384.62
153.	168.94	6.25	32534.21	50759.38	-50.00	192.00	6.00	29453.09	53967.25	-30.00	4447.88
154.	168.94	6.25	32574.68	50552.30	-50.00	192.00	6.00	29410.95	53768.98	-30.00	4511.78
155.	168.94	6.25	32615.15	50345.22	-50.00	178.00	6.00	29368.81	53570.71	-30.00	4576.30
156.	168.94	6.25	32655.62	50138.14	-50.00	178.00	6.00	29375.88	53368.14	-30.00	4603.21
157.	168.94	6.25	32696.09	49931.06	-50.00	178.00	6.00	29382.96	53165.56	-30.00	4630.21
158.	168.94	6.25	32736.56	49723.97	-50.00	178.00	6.00	29390.03	52962.99	-30.00	4657.30
159.	168.94	6.25	32777.03	49516.89	-50.00	178.00	6.00	29397.10	52760.41	-30.00	4684.48
160.	168.94	6.25	32817.50	49309.81	-50.00	184.00	6.00	29404.18	52557.84	-30.00	4711.74
161.	168.94	6.25	32857.97	49102.73	-50.00	184.00	6.00	29390.04	52355.64	-30.00	4754.78
162.	168.94	6.25	32898.44	48895.65	-50.00	184.00	6.00	29375.90	52153.43	-30.00	4798.07
163.	168.94	6.25	32938.91	48688.56	-50.00	184.00	6.00	29361.76	51951.23	-30.00	4841.59
164.	168.94	6.25	32979.38	48481.48	-50.00	184.00	6.00	29347.62	51749.02	-30.00	4885.34
165.	168.94	6.25	33019.85	48274.40	-50.00	173.00	6.00	29333.48	51546.82	-30.00	4929.31
166.	168.94	6.25	33060.32	48067.32	-50.00	173.00	6.00	29358.18	51345.63	-30.00	4945.01
167.	168.94	6.25	33100.79	47860.24	-50.00	173.00	6.00	29382.89	51144.44	-30.00	4960.73
168.	168.94	6.25	33141.26	47653.15	-50.00	173.00	6.00	29407.59	50943.26	-30.00	4976.45
169.	168.94	6.25	33181.73	47446.07	-50.00	173.00	6.00	29432.29	50742.07	-30.00	4992.19
170.	168.94	6.25	33222.20	47238.99	-50.00	198.00	6.00	29456.99	50540.88	-30.00	5007.92
171.	168.94	6.25	33262.67	47031.91	-50.00	198.00	6.00	29394.36	50348.11	-30.00	5095.20
172.	168.94	6.25	33303.14	46824.83	-50.00	198.00	6.00	29331.72	50155.33	-30.00	5183.09
173.	168.94	6.25	33343.61	46617.74	-50.00	198.00	6.00	29269.08	49962.55	-30.00	5271.58
174.	168.94	6.25	33384.08	46410.66	-50.00	198.00	6.00	29206.45	49769.78	-30.00	5360.63
175.	168.94	6.25	33424.55	46203.58	-50.00	160.00	6.00	29143.81	49577.00	-30.00	5450.21
176.	168.94	6.25	33465.02	45996.50	-50.00	160.00	6.00	29213.14	49386.53	-30.00	5437.91
177.	168.94	6.25	33505.49	45789.42	-50.00	160.00	6.00	29282.46	49196.05	-30.00	5425.79
178.	168.94	6.25	33545.96	45582.33	-50.00	160.00	6.00	29351.79	49005.58	-30.00	5413.84
179.	168.94	6.25	33586.43	45375.25	-50.00	160.00	6.00	29421.12	48815.11	-30.00	5402.08

SHIP POSITIONS

	BARRIER BOAT					PENETRATOR BOAT					
TIME	HEADING	SPEED	X	Y	Z	HEADING	SPEED	X	Y	Z	RHO
180.	168.94	6.25	33626.90	45168.17	-50.00	187.00	6.00	29490.44	48624.63	-30.00	5390.50
181.	168.94	6.25	33667.38	44961.09	-50.00	187.00	6.00	29465.74	48423.44	-30.00	5444.41
182.	168.94	6.25	33707.85	44754.01	-50.00	187.00	6.00	29441.04	48222.26	-30.00	5498.58
183.	168.94	6.25	33748.32	44546.92	-50.00	187.00	6.00	29416.34	48021.07	-30.00	5553.00
184.	168.94	6.25	33788.79	44339.84	-50.00	187.00	6.00	29391.63	47819.88	-30.00	5607.64
185.	168.94	6.25	33829.26	44132.76	-50.00	166.00	6.00	29366.93	47618.70	-30.00	5662.52
186.	168.94	6.25	33869.73	43925.68	-50.00	166.00	6.00	29415.97	47422.02	-30.00	5662.19
187.	168.94	6.25	33910.20	43718.60	-50.00	166.00	6.00	29465.00	47225.34	-30.00	5661.89
188.	168.94	6.25	33950.67	43511.51	-50.00	166.00	6.00	29514.04	47028.67	-30.00	5661.63
189.	168.94	6.25	33991.14	43304.43	-50.00	166.00	6.00	29563.08	46831.99	-30.00	5661.39
190.	168.94	6.25	34031.61	43097.35	-50.00	171.00	6.00	29612.11	46635.31	-30.00	5661.19
191.	168.94	6.25	34072.08	42890.27	-50.00	171.00	6.00	29643.82	46435.11	-30.00	5672.33
192.	168.94	6.25	34112.55	42683.18	-50.00	171.00	6.00	29675.53	46234.91	-30.00	5683.47
193.	168.94	6.25	34153.02	42476.10	-50.00	171.00	6.00	29707.24	46034.71	-30.00	5694.61
194.	168.94	6.25	34193.49	42269.02	-50.00	171.00	6.00	29738.95	45834.50	-30.00	5705.75
195.	168.94	6.25	34233.96	42061.94	-50.00	178.00	6.00	29770.66	45634.30	-30.00	5716.89
196.	168.94	6.25	34274.43	41854.86	-50.00	178.00	6.00	29777.73	45431.73	-30.00	5745.81
197.	168.94	6.25	34314.90	41647.77	-50.00	178.00	6.00	29784.81	45229.15	-30.00	5774.77
198.	168.94	6.25	34355.37	41440.69	-50.00	178.00	6.00	29791.88	45026.58	-30.00	5803.79
199.	168.94	6.25	34395.84	41233.61	-50.00	178.00	6.00	29798.95	44824.00	-30.00	5832.86
200.	168.94	6.25	34436.31	41026.53	-50.00	160.00	6.00	29806.03	44621.43	-30.00	5861.98
201.	168.94	6.25	34476.78	40819.45	-50.00	160.00	6.00	29875.35	44430.96	-30.00	5849.45
202.	168.94	6.25	34517.25	40612.36	-50.00	160.00	6.00	29944.68	44240.48	-30.00	5837.09
203.	168.94	6.25	34557.72	40405.28	-50.00	160.00	6.00	30014.01	44050.01	-30.00	5824.89
204.	168.94	6.25	34598.19	40198.20	-50.00	160.00	6.00	30083.33	43859.54	-30.00	5812.86
205.	168.94	6.25	34638.66	39991.12	-50.00	196.00	6.00	30152.66	43669.06	-30.00	5800.99
206.	168.94	6.25	34679.13	39784.04	-50.00	196.00	6.00	30096.79	43474.22	-30.00	5883.47
207.	168.94	6.25	34719.60	39576.95	-50.00	196.00	6.00	30040.92	43279.37	-30.00	5966.40
208.	168.94	6.25	34760.07	39369.87	-50.00	196.00	6.00	29985.05	43084.53	-30.00	6049.75
209.	168.94	6.25	34800.54	39162.79	-50.00	196.00	6.00	29929.18	42889.68	-30.00	6133.51
210.	168.94	6.25	34841.01	38955.71	-50.00	181.00	6.00	29873.31	42694.83	-30.00	6217.65
211.	168.94	6.25	34881.48	38748.63	-50.00	181.00	6.00	29869.77	42492.17	-30.00	6255.51
212.	168.94	6.25	34921.95	38541.54	-50.00	181.00	6.00	29866.23	42289.50	-30.00	6293.45
213.	168.94	6.25	34962.42	38334.46	-50.00	181.00	6.00	29862.69	42086.83	-30.00	6331.47
214.	168.94	6.25	35002.89	38127.38	-50.00	181.00	6.00	29859.16	41884.17	-30.00	6369.57
215.	168.94	6.25	35043.36	37920.30	-50.00	174.00	6.00	29855.62	41681.50	-30.00	6407.75

SHIP POSITIONS

	CARRIER BOAT					PENETRATOR BOAT					
TIME	HEADING	SPEED	X	Y	Z	HEADING	SPEED	X	Y	Z	RHO
216.	168.94	6.25	35083.83	37713.22	-50.00	174.00	6.00	29876.81	41479.91	-30.00	6426.59
217.	168.94	6.25	35124.30	37506.13	-50.00	174.00	6.00	29897.99	41278.32	-30.00	6445.44
218.	168.94	6.25	35164.77	37299.05	-50.00	174.00	6.00	29919.18	41076.74	-30.00	6464.30
219.	168.94	6.25	35205.24	37091.97	-50.00	174.00	6.00	29940.37	40875.15	-30.00	6483.16
220.	168.94	6.25	35245.71	36884.89	-50.00	193.00	6.00	29961.56	40673.56	-30.00	6502.03
221.	168.94	6.25	35286.18	36677.81	-50.00	193.00	6.00	29915.96	40476.06	-30.00	6577.69
222.	168.94	6.25	35326.65	36470.72	-50.00	193.00	6.00	29870.36	40278.56	-30.00	6653.62
223.	168.94	6.25	35367.12	36263.64	-50.00	193.00	6.00	29824.77	40081.05	-30.00	6729.81
224.	168.94	6.25	35407.59	36056.56	-50.00	193.00	6.00	29779.17	39883.55	-30.00	6806.25
225.	168.94	6.25	35448.06	35849.48	-50.00	181.00	6.00	29733.57	39686.05	-30.00	6882.93
226.	168.94	6.25	35488.53	35642.40	-50.00	181.00	6.00	29730.03	39483.38	-30.00	6921.96
227.	168.94	6.25	35529.00	35435.31	-50.00	181.00	6.00	29726.50	39280.72	-30.00	6961.05
228.	168.94	6.25	35569.47	35228.23	-50.00	181.00	6.00	29722.96	39078.05	-30.00	7000.20
229.	168.94	6.25	35609.94	35021.15	-50.00	181.00	6.00	29719.42	38875.38	-30.00	7039.42
230.	168.94	6.25	35650.42	34814.07	-50.00	186.00	6.00	29715.89	38672.71	-30.00	7078.69
231.	168.94	6.25	35690.89	34606.99	-50.00	186.00	6.00	29694.70	38471.13	-30.00	7133.43
232.	351.58	3.00	35731.36	34399.90	-30.00	186.00	6.00	29673.51	38269.54	-30.00	7188.30
233.	351.58	3.00	35716.51	34500.16	-30.00	186.00	6.00	29652.32	38067.95	-30.00	7035.88
234.	351.58	3.00	35701.67	34600.42	-30.00	186.00	6.00	29631.13	37866.37	-30.00	6893.32
235.	351.58	3.00	35686.83	34700.67	-30.00	168.00	6.00	29609.95	37664.78	-30.00	6761.24
236.	351.58	3.00	35671.99	34800.93	-30.00	168.00	6.00	29652.09	37466.51	-30.00	6583.65
237.	351.58	3.00	35657.14	34901.18	-30.00	168.00	6.00	29694.23	37268.24	-30.00	6415.55
238.	351.58	3.00	35642.30	35001.44	-30.00	168.00	6.00	29736.38	37069.97	-30.00	6257.70
239.	351.58	3.00	35627.46	35101.69	-30.00	168.00	6.00	29778.52	36871.70	-30.00	6110.89
240.	351.58	3.00	35612.61	35201.95	-30.00	174.00	6.00	29820.66	36673.43	-30.00	5975.95
241.	351.58	3.00	35597.77	35302.21	-30.00	174.00	6.00	29841.85	36471.85	-30.00	5873.56
242.	351.58	3.00	35582.93	35402.46	-30.00	174.00	6.00	29863.04	36270.26	-30.00	5785.35
243.	351.58	3.00	35568.09	35502.72	-30.00	174.00	6.00	29884.23	36068.67	-30.00	5711.97
244.	351.58	3.00	35553.24	35602.97	-30.00	174.00	6.00	29905.41	35867.09	-30.00	5654.00
245.	351.58	3.00	35538.40	35703.23	-30.00	180.00	6.00	29926.60	35665.50	-30.00	5611.93
246.	351.58	3.00	35523.56	35803.49	-30.00	180.00	6.00	29926.60	35462.80	-30.00	5607.32
247.	351.58	3.00	35508.71	35903.74	-30.00	180.00	6.00	29926.60	35260.10	-30.00	5619.10
248.	351.58	3.00	35493.87	36004.00	-30.00	180.00	6.00	29926.60	35057.40	-30.00	5647.17
249.	351.58	3.00	35479.03	36104.25	-30.00	180.00	6.00	29926.60	34854.71	-30.00	5691.29
250.	351.58	3.00	35464.19	36204.51	-30.00	189.00	6.00	29926.60	34652.01	-10.00	5751.10
251.	351.58	3.00	35449.34	36304.76	-30.00	189.00	6.00	29894.89	34451.81	-10.00	5855.37

UNCLASSIFIED

BARRIER/PENETRATOR RUN 040 DATE 120567 PAGE 20

SHIP POSITIONS

	CARRIER BOAT					PENETRATOR BOAT					
TIME	HEADING	SPEED	X	Y	Z	HEADING	SPEED	X	Y	Z	RHO
252.	351.56	3.00	35434.50	36405.02	-30.00	189.00	6.00	29863.18	34251.60	-10.00	5973.00
253.	166.87	3.00	35419.66	36505.28	-30.00	189.00	6.00	29831.47	34051.40	-10.00	6103.22
254.	166.87	3.00	35404.03	36405.14	-30.00	189.00	6.00	29799.77	33851.20	-10.00	6158.77
255.	166.87	3.00	35388.41	36305.00	-30.00	171.00	6.00	29768.06	33651.00	-10.00	6215.47
256.	166.87	3.00	35372.79	36204.86	-30.00	171.00	6.00	29799.77	33450.80	-10.00	6216.39

UNCLASSIFIED

SUBSYSTEM VALUES

TIME	TACTIC	SNORK	AVE S/N	S/N	BARRIER SHIP VALUES PROB D	D.BEARING	D.B ERR	P.BEAR	P.B ERR	P.RANGE	P.R ERR
1.	1	0	-27.30	-27.30	.00	304.84	.17	.00	.00	.00	.00
2.	1	0	-27.07	-26.34	.14	307.76	-.01	.00	.00	.00	.00
3.	1	0	-26.83	-26.36	.17	310.71	-.21	.00	.00	.00	.00
4.	1	0	-26.60	-25.88	.19	314.43	.33	.00	.00	.00	.00
5.	2	0	-26.36	-25.40	.26	317.41	.06	.00	.00	.00	.00
6.	2	0	-26.36	-25.00	.26	318.58	.38	-57.30	.00	-1.00	.00
7.	2	0	-26.36	-24.70	.26	290.39	-.19	290.60	.02	6160.95	58.15
8.	2	0	-26.36	-24.44	.26	291.22	-.03	291.44	.19	6213.15	263.80
9.	2	0	-26.36	-24.29	.26	292.04	.08	292.40	.44	5374.51	-422.27
10.	2	0	-26.36	-24.14	.26	292.87	.17	292.39	-.32	5434.74	-210.39
11.	2	0	-26.36	-23.92	.26	293.06	.22	292.61	-.23	5301.98	-131.11
12.	2	0	-26.36	-23.71	.26	293.21	.23	292.77	-.21	5119.69	-101.40
13.	2	0	-26.36	-23.50	.26	293.32	.19	292.89	-.23	4901.51	-107.60
14.	2	0	-26.36	-22.88	.26	293.40	.12	292.95	-.34	4649.11	-148.07
15.	2	0	-26.36	-22.25	.26	293.48	.01	293.85	.38	4342.03	-243.25
16.	2	0	-26.36	-21.80	.26	294.35	-.12	294.63	.16	4707.03	271.21
17.	2	0	-26.36	-21.35	.26	295.12	-.42	295.53	-.00	4376.11	88.31
18.	2	0	-26.36	-20.91	.26	296.83	.15	296.46	-.22	4092.76	-48.63
19.	2	0	-26.36	-20.48	.26	297.82	-.10	298.14	.23	3702.28	-294.47
20.	2	0	-26.36	-20.05	.26	299.58	.34	299.17	-.06	3912.59	58.51
21.	2	0	-26.36	-19.44	.26	299.85	-.04	300.25	.36	3504.94	-144.55
22.	6	0	-26.36	-18.83	.26	300.93	.30	300.56	-.06	3508.85	63.42
23.	6	0	-26.36	-18.22	.26	301.31	-.14	301.67	.22	3055.57	-186.44
24.	6	0		-41.03	.00	-57.30	.00	-57.30	.00	-1.00	.00
25.	6	0		-41.00	.00	-57.30	.00	-57.30	.00	-1.00	.00
26.	6	0		-40.96	.00	-57.30	.00	-57.30	.00	-1.00	.00
27.	6	0		-40.91	.00	-57.30	.00	-57.30	.00	-1.00	.00
28.	6	0		-40.87	.00	-57.30	.00	-57.30	.00	-1.00	.00
29.	6	0		-40.83	.00	-57.30	.00	-57.30	.00	-1.00	.00
30.	6	0		-40.09	.00	-57.30	.00	-57.30	.00	-1.00	.00
31.	6	0		-39.93	.00	-57.30	.00	-57.30	.00	-1.00	.00
32.	6	0		-39.77	.00	-57.30	.00	-57.30	.00	-1.00	.00
33.	6	0		-39.61	.00	-57.30	.00	-57.30	.00	-1.00	.00
34.	6	0		-39.45	.00	-57.30	.00	-57.30	.00	-1.00	.00
35.	6	0		-39.30	.00	-57.30	.00	-57.30	.00	-1.00	.00

SUBSYSTEM VALUES

BARRIER SHIP VALUES

TIME	TACTIC	SNORK	AVE S/N	S/N	PROB D	D.BEARING	D.B ERR	P.BEAR	P.B ERR	P.RANGE	P.R ERR
36.	6	0		-39.83	.00	-57.30	.00	-57.30	.00	-1.00	.00
37.	6	0		-40.36	.00	-57.30	.00	-57.30	.00	-1.00	.00
38.	6	0		-40.83	.00	-57.30	.00	-57.30	.00	-1.00	.00
39.	6	0		-40.85	.00	-57.30	.00	-57.30	.00	-1.00	.00
40.	6	0		-40.68	.00	-57.30	.00	-57.30	.00	-1.00	.00
41.	6	0		-58.15	.00	-57.30	.00	-57.30	.00	-1.00	.00
42.	6	0		-58.14	.00	-57.30	.00	-57.30	.00	-1.00	.00
43.	6	0		-58.13	.00	-57.30	.00	-57.30	.00	-1.00	.00
44.	6	0		-58.11	.00	-57.30	.00	-57.30	.00	-1.00	.00
45.	6	0		-58.00	.00	-57.30	.00	-57.30	.00	-1.00	.00
46.	6	0		-57.86	.00	-57.30	.00	-57.30	.00	-1.00	.00
47.	6	0		-57.72	.00	-57.30	.00	-57.30	.00	-1.00	.00
48.	6	0		-57.59	.00	-57.30	.00	-57.30	.00	-1.00	.00
49.	6	0		-57.45	.00	-57.30	.00	-57.30	.00	-1.00	.00
50.	6	0		-57.33	.00	-57.30	.00	-57.30	.00	-1.00	.00
51.	6	0		-57.15	.00	-57.30	.00	-57.30	.00	-1.00	.00
52.	6	0		-56.98	.00	-57.30	.00	-57.30	.00	-1.00	.00
53.	6	0		-56.81	.00	-57.30	.00	-57.30	.00	-1.00	.00
54.	6	0		-56.65	.00	-57.30	.00	-57.30	.00	-1.00	.00
55.	6	0		-56.49	.00	-57.30	.00	-57.30	.00	-1.00	.00
56.	6	0		-55.86	.00	-57.30	.00	-57.30	.00	-1.00	.00
57.	6	0		-55.26	.00	-57.30	.00	-57.30	.00	-1.00	.00
58.	6	0		-54.69	.00	-57.30	.00	-57.30	.00	-1.00	.00
59.	6	0		-54.15	.00	-57.30	.00	-57.30	.00	-1.00	.00
60.	6	0		-53.64	.00	-57.30	.00	-57.30	.00	-1.00	.00
61.	6	0		-54.17	.00	-57.30	.00	-57.30	.00	-1.00	.00
62.	6	0		-54.70	.00	-57.30	.00	-57.30	.00	-1.00	.00
63.	6	0		-55.24	.00	-57.30	.00	-57.30	.00	-1.00	.00
64.	6	0		-55.78	.00	-57.30	.00	-57.30	.00	-1.00	.00
65.	6	0		-56.32	.00	-57.30	.00	-57.30	.00	-1.00	.00
66.	6	0		-55.87	.00	-57.30	.00	-57.30	.00	-1.00	.00
67.	6	0		-55.45	.00	-57.30	.00	-57.30	.00	-1.00	.00
68.	6	0		-55.05	.00	-57.30	.00	-57.30	.00	-1.00	.00
69.	6	0		-54.68	.00	-57.30	.00	-57.30	.00	-1.00	.00
70.	6	0		-54.32	.00	-57.30	.00	-57.30	.00	-1.00	.00
71.	6	0		-53.94	.00	-57.30	.00	-57.30	.00	-1.00	.00

SUBSYSTEM VALUES

TIME	TACTIC	SNORK	AVE S/N	S/N	BARRIER SHIP VALUES PROB D	D.BEARING	D.B ERR	P.BEAR	P.B ERR	P.RANGE	P.R ERR
72.	6	0		-53.60	.00	-57.30	.00	-57.30	.00	-1.00	.00
73.	6	0		-53.29	.00	-57.30	.00	-57.30	.00	-1.00	.00
74.	6	0		-53.01	.00	-57.30	.00	-57.30	.00	-1.00	.00
75.	6	0		-52.77	.00	-57.30	.00	-57.30	.00	-1.00	.00
76.	6	0		-52.61	.00	-57.30	.00	-57.30	.00	-1.00	.00
77.	6	0		-52.46	.00	-57.30	.00	-57.30	.00	-1.00	.00
78.	6	0		-52.34	.00	-57.30	.00	-57.30	.00	-1.00	.00
79.	6	0		-52.24	.00	-57.30	.00	-57.30	.00	-1.00	.00
80.	6	0		-52.17	.00	-57.30	.00	-57.30	.00	-1.00	.00
81.	6	0		-52.13	.00	-57.30	.00	-57.30	.00	-1.00	.00
82.	6	0		-52.15	.00	-57.30	.00	-57.30	.00	-1.00	.00
83.	6	0		-52.22	.00	-57.30	.00	-57.30	.00	-1.00	.00
84.	6	0		-52.34	.00	-57.30	.00	-57.30	.00	-1.00	.00
85.	6	0		-52.52	.00	-57.30	.00	-57.30	.00	-1.00	.00
86.	6	0		-52.68	.00	-57.30	.00	-57.30	.00	-1.00	.00
87.	6	0		-52.87	.00	-57.30	.00	-57.30	.00	-1.00	.00
88.	6	0		-53.09	.00	-57.30	.00	-57.30	.00	-1.00	.00
89.	6	0		-53.35	.00	-57.30	.00	-57.30	.00	-1.00	.00
90.	6	0		-53.64	.00	-57.30	.00	-57.30	.00	-1.00	.00
91.	6	0		-54.02	.00	-57.30	.00	-57.30	.00	-1.00	.00
92.	6	0		-54.45	.00	-57.30	.00	-57.30	.00	-1.00	.00
93.	6	0		-54.92	.00	-57.30	.00	-57.30	.00	-1.00	.00
94.	6	0		-55.42	.00	-57.30	.00	-57.30	.00	-1.00	.00
95.	6	0		-55.97	.00	-57.30	.00	-57.30	.00	-1.00	.00
96.	6	0		-56.22	.00	-57.30	.00	-57.30	.00	-1.00	.00
97.	6	0		-56.47	.00	-57.30	.00	-57.30	.00	-1.00	.00
98.	6	0		-56.72	.00	-57.30	.00	-57.30	.00	-1.00	.00
99.	6	0		-56.98	.00	-57.30	.00	-57.30	.00	-1.00	.00
100.	6	0		-57.24	.00	-57.30	.00	-57.30	.00	-1.00	.00
101.	6	0		-57.76	.00	-57.30	.00	-57.30	.00	-1.00	.00
102.	6	0		-58.12	.00	-57.30	.00	-57.30	.00	-1.00	.00
103.	6	0		-58.14	.00	-57.30	.00	-57.30	.00	-1.00	.00
104.	6	0		-58.17	.00	-57.30	.00	-57.30	.00	-1.00	.00
105.	6	0		-58.20	.00	-57.30	.00	-57.30	.00	-1.00	.00
106.	6	0		-58.22	.00	-57.30	.00	-57.30	.00	-1.00	.00
107.	6	0		-58.23	.00	-57.30	.00	-57.30	.00	-1.00	.00

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SUBSYSTEM VALUES

					BARRIER SHIP VALUES						
TIME	TACTIC	SNORK	AVE S/N	S/N	PROP D	D.BEARING	D.B ERR	P.BEAR	P.B ERR	P.RANGE	P.R ERR
108.	6	0		-58.25	.00	-57.30	.00	-57.30	.00	-1.00	.00
109.	6	0		-58.27	.00	-57.30	.00	-57.30	.00	-1.00	.00
110.	6	0		-58.29	.00	-57.30	.00	-57.30	.00	-1.00	.00
111.	6	0		-58.34	.00	-57.30	.00	-57.30	.00	-1.00	.00
112.	6	0		-58.39	.00	-57.30	.00	-57.30	.00	-1.00	.00
113.	6	0		-58.44	.00	-57.30	.00	-57.30	.00	-1.00	.00
114.	6	0		-58.50	.00	-57.30	.00	-57.30	.00	-1.00	.00
115.	6	0		-58.55	.00	-57.30	.00	-57.30	.00	-1.00	.00
116.	6	0		-58.59	.00	-57.30	.00	-57.30	.00	-1.00	.00
117.	6	0		-58.63	.00	-57.30	.00	-57.30	.00	-1.00	.00
118.	6	0		-58.66	.00	-57.30	.00	-57.30	.00	-1.00	.00
119.	6	0		-58.70	.00	-57.30	.00	-57.30	.00	-1.00	.00
120.	6	0		-58.74	.00	-57.30	.00	-57.30	.00	-1.00	.00
121.	6	0		-58.76	.00	-57.30	.00	-57.30	.00	-1.00	.00
122.	6	0		-58.77	.00	-57.30	.00	-57.30	.00	-1.00	.00
123.	6	0		-58.79	.00	-57.30	.00	-57.30	.00	-1.00	.00
124.	6	0		-58.80	.00	-57.30	.00	-57.30	.00	-1.00	.00
125.	6	0		-58.81	.00	-57.30	.00	-57.30	.00	-1.00	.00
126.	6	0		-58.82	.00	-57.30	.00	-57.30	.00	-1.00	.00
127.	6	0		-58.82	.00	-57.30	.00	-57.30	.00	-1.00	.00
128.	6	0		-58.82	.00	-57.30	.00	-57.30	.00	-1.00	.00
129.	6	0		-58.82	.00	-57.30	.00	-57.30	.00	-1.00	.00
130.	6	0		-58.83	.00	-57.30	.00	-57.30	.00	-1.00	.00
131.	6	0		-58.88	.00	-57.30	.00	-57.30	.00	-1.00	.00
132.	6	0		-58.94	.00	-57.30	.00	-57.30	.00	-1.00	.00
133.	6	0		-58.99	.00	-57.30	.00	-57.30	.00	-1.00	.00
134.	6	0		-59.05	.00	-57.30	.00	-57.30	.00	-1.00	.00
135.	6	0		-59.11	.00	-57.30	.00	-57.30	.00	-1.00	.00
136.	6	0		-59.12	.00	-57.30	.00	-57.30	.00	-1.00	.00
137.	6	0		-59.14	.00	-57.30	.00	-57.30	.00	-1.00	.00
138.	6	0		-59.15	.00	-57.30	.00	-57.30	.00	-1.00	.00
139.	6	0		-59.17	.00	-57.30	.00	-57.30	.00	-1.00	.00
140.	6	0		-59.18	.00	-57.30	.00	-57.30	.00	-1.00	.00
141.	6	0		-59.19	.00	-57.30	.00	-57.30	.00	-1.00	.00
142.	6	0		-59.19	.00	-57.30	.00	-57.30	.00	-1.00	.00
143.	6	0		-59.20	.00	-57.30	.00	-57.30	.00	-1.00	.00

SUBSYSTEM VALUES

BARRIER SHIP VALUES

TIME	TACTIC	SNORK	AVE S/N	S/N	PROB D	D.BEARING	D.B ERR	P.BEAR	P.B ERR	P.RANGE	P.R ERR
144.	6	0		-59.20	.00	-57.30	.00	-57.30	.00	-1.00	.00
145.	6	0		-59.21	.00	-57.30	.00	-57.30	.00	-1.00	.00
146.	6	0		-59.21	.00	-57.30	.00	-57.30	.00	-1.00	.00
147.	6	0		-59.22	.00	-57.30	.00	-57.30	.00	-1.00	.00
148.	6	0		-59.23	.00	-57.30	.00	-57.30	.00	-1.00	.00
149.	6	0		-59.23	.00	-57.30	.00	-57.30	.00	-1.00	.00
150.	6	0		-59.24	.00	-57.30	.00	-57.30	.00	-1.00	.00
151.	6	0		-59.27	.00	-57.30	.00	-57.30	.00	-1.00	.00
152.	6	0		-59.30	.00	-57.30	.00	-57.30	.00	-1.00	.00
153.	6	0		-59.33	.00	-57.30	.00	-57.30	.00	-1.00	.00
154.	6	0		-59.36	.00	-57.30	.00	-57.30	.00	-1.00	.00
155.	6	0		-59.40	.00	-57.30	.00	-57.30	.00	-1.00	.00
156.	6	0		-59.41	.00	-57.30	.00	-57.30	.00	-1.00	.00
157.	6	0		-59.42	.00	-57.30	.00	-57.30	.00	-1.00	.00
158.	6	0		-59.44	.00	-57.30	.00	-57.30	.00	-1.00	.00
159.	6	0		-59.45	.00	-57.30	.00	-57.30	.00	-1.00	.00
160.	6	0		-59.46	.00	-57.30	.00	-57.30	.00	-1.00	.00
161.	6	0		-59.49	.00	-57.30	.00	-57.30	.00	-1.00	.00
162.	6	0		-59.51	.00	-57.30	.00	-57.30	.00	-1.00	.00
163.	6	0		-59.53	.00	-57.30	.00	-57.30	.00	-1.00	.00
164.	6	0		-59.55	.00	-57.30	.00	-57.30	.00	-1.00	.00
165.	6	0		-59.57	.00	-57.30	.00	-57.30	.00	-1.00	.00
166.	6	0		-59.58	.00	-57.30	.00	-57.30	.00	-1.00	.00
167.	6	0		-59.59	.00	-57.30	.00	-57.30	.00	-1.00	.00
168.	6	0		-59.60	.00	-57.30	.00	-57.30	.00	-1.00	.00
169.	6	0		-59.60	.00	-57.30	.00	-57.30	.00	-1.00	.00
170.	6	0		-59.62	.00	-57.30	.00	-57.30	.00	-1.00	.00
171.	6	0		-59.70	.00	-57.30	.00	-57.30	.00	-1.00	.00
172.	6	0		-59.79	.00	-57.30	.00	-57.30	.00	-1.00	.00
173.	6	0		-59.88	.00	-57.30	.00	-57.30	.00	-1.00	.00
174.	6	0		-59.97	.00	-57.30	.00	-57.30	.00	-1.00	.00
175.	6	0		-60.06	.00	-57.30	.00	-57.30	.00	-1.00	.00
176.	6	0		-60.05	.00	-57.30	.00	-57.30	.00	-1.00	.00
177.	6	0		-60.03	.00	-57.30	.00	-57.30	.00	-1.00	.00
178.	6	0		-60.02	.00	-57.30	.00	-57.30	.00	-1.00	.00
179.	6	0		-60.01	.00	-57.30	.00	-57.30	.00	-1.00	.00

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SUBSYSTEM VALUES

BARRIER SHIP VALUES

TIME	TACTIC	SNORK	AVE S/N	S/N	PROB D	D.BEARING	D.B ERR	P.BEAR	P.B ERR	P.RANGE	P.R ERR
180.	6	0		-60.00	.00	-57.30	.00	-57.30	.00	-1.00	.00
181.	6	0		-60.05	.00	-57.30	.00	-57.30	.00	-1.00	.00
182.	6	0		-60.11	.00	-57.30	.00	-57.30	.00	-1.00	.00
183.	6	0		-60.16	.00	-57.30	.00	-57.30	.00	-1.00	.00
184.	6	0		-60.22	.00	-57.30	.00	-57.30	.00	-1.00	.00
185.	6	0		-60.27	.00	-57.30	.00	-57.30	.00	-1.00	.00
186.	6	0		-60.27	.00	-57.30	.00	-57.30	.00	-1.00	.00
187.	6	0		-60.27	.00	-57.30	.00	-57.30	.00	-1.00	.00
188.	6	0		-60.27	.00	-57.30	.00	-57.30	.00	-1.00	.00
189.	6	0		-60.27	.00	-57.30	.00	-57.30	.00	-1.00	.00
190.	6	0		-60.27	.00	-57.30	.00	-57.30	.00	-1.00	.00
191.	6	0		-60.28	.00	-57.30	.00	-57.30	.00	-1.00	.00
192.	6	0		-60.29	.00	-57.30	.00	-57.30	.00	-1.00	.00
193.	6	0		-60.30	.00	-57.30	.00	-57.30	.00	-1.00	.00
194.	6	0		-60.31	.00	-57.30	.00	-57.30	.00	-1.00	.00
195.	6	0		-60.33	.00	-57.30	.00	-57.30	.00	-1.00	.00
196.	6	0		-60.35	.00	-57.30	.00	-57.30	.00	-1.00	.00
197.	6	0		-60.38	.00	-57.30	.00	-57.30	.00	-1.00	.00
198.	6	0		-60.41	.00	-57.30	.00	-57.30	.00	-1.00	.00
199.	6	0		-60.44	.00	-57.30	.00	-57.30	.00	-1.00	.00
200.	6	0		-60.47	.00	-57.30	.00	-57.30	.00	-1.00	.00
201.	6	0		-60.46	.00	-57.30	.00	-57.30	.00	-1.00	.00
202.	6	0		-60.45	.00	-57.30	.00	-57.30	.00	-1.00	.00
203.	6	0		-60.43	.00	-57.30	.00	-57.30	.00	-1.00	.00
204.	6	0		-60.42	.00	-57.30	.00	-57.30	.00	-1.00	.00
205.	6	0		-60.41	.00	-57.30	.00	-57.30	.00	-1.00	.00
206.	6	0		-60.49	.00	-57.30	.00	-57.30	.00	-1.00	.00
207.	6	0		-60.57	.00	-57.30	.00	-57.30	.00	-1.00	.00
208.	6	0		-60.63	.00	-57.30	.00	-57.30	.00	-1.00	.00
209.	6	0		-60.67	.00	-57.30	.00	-57.30	.00	-1.00	.00
210.	6	0		-60.72	.00	-57.30	.00	-57.30	.00	-1.00	.00
211.	6	0		-60.74	.00	-57.30	.00	-57.30	.00	-1.00	.00
212.	6	0		-60.75	.00	-57.30	.00	-57.30	.00	-1.00	.00
213.	6	0		-60.77	.00	-57.30	.00	-57.30	.00	-1.00	.00
214.	6	0		-60.79	.00	-57.30	.00	-57.30	.00	-1.00	.00
215.	6	0		-60.81	.00	-57.30	.00	-57.30	.00	-1.00	.00

UNCLASSIFIED

SUBSYSTEM VALUES

BARRIER SHIP VALUES

TIME	TACTIC	SNORK	AVE S/N	S/N	PROB D	O.BEARING	O.B ERR	P.BEAR	P.B ERR	P.RANGE	P.R ERR
216.	6	0		-60.82	.00	-57.30	.00	-57.30	.00	-1.00	.00
217.	6	0		-60.83	.00	-57.30	.00	-57.30	.00	-1.00	.00
218.	6	0		-60.84	.00	-57.30	.00	-57.30	.00	-1.00	.00
219.	6	0		-60.85	.00	-57.30	.00	-57.30	.00	-1.00	.00
220.	6	0		-60.86	.00	-57.30	.00	-57.30	.00	-1.00	.00
221.	6	0		-60.90	.00	-57.30	.00	-57.30	.00	-1.00	.00
222.	6	0		-60.93	.00	-57.30	.00	-57.30	.00	-1.00	.00
223.	6	0		-60.97	.00	-57.30	.00	-57.30	.00	-1.00	.00
224.	6	0		-61.01	.00	-57.30	.00	-57.30	.00	-1.00	.00
225.	6	0		-61.05	.00	-57.30	.00	-57.30	.00	-1.00	.00
226.	6	0		-61.07	.00	-57.30	.00	-57.30	.00	-1.00	.00
227.	6	0		-61.09	.00	-57.30	.00	-57.30	.00	-1.00	.00
228.	6	0		-61.11	.00	-57.30	.00	-57.30	.00	-1.00	.00
229.	6	0		-61.15	.00	-57.30	.00	-57.30	.00	-1.00	.00
230.	6	0		-61.19	.00	-57.30	.00	-57.30	.00	-1.00	.00
231.	6	0		-61.24	.00	-57.30	.00	-57.30	.00	-1.00	.00
232.	6	0		-61.30	.00	-57.30	.00	-57.30	.00	-1.00	.00
233.	6	0		-43.85	.00	-57.30	.00	-57.30	.00	-1.00	.00
234.	6	0		-43.56	.00	-57.30	.00	-57.30	.00	-1.00	.00
235.	6	0		-43.30	.00	-57.30	.00	-57.30	.00	-1.00	.00
236.	6	0		-42.94	.00	-57.30	.00	-57.30	.00	-1.00	.00
237.	6	0		-42.61	.00	-57.30	.00	-57.30	.00	-1.00	.00
238.	6	0		-42.29	.00	-57.30	.00	-57.30	.00	-1.00	.00
239.	6	0		-42.00	.00	-57.30	.00	-57.30	.00	-1.00	.00
240.	6	0		-41.75	.00	-57.30	.00	-57.30	.00	-1.00	.00
241.	6	0		-41.65	.00	-57.30	.00	-57.30	.00	-1.00	.00
242.	6	0		-41.56	.00	-57.30	.00	-57.30	.00	-1.00	.00
243.	6	0		-41.49	.00	-57.30	.00	-57.30	.00	-1.00	.00
244.	6	0		-41.43	.00	-57.30	.00	-57.30	.00	-1.00	.00
245.	6	0		-41.39	.00	-57.30	.00	-57.30	.00	-1.00	.00
246.	6	0		-41.38	.00	-57.30	.00	-57.30	.00	-1.00	.00
247.	6	0		-41.40	.00	-57.30	.00	-57.30	.00	-1.00	.00
248.	6	0		-41.42	.00	-57.30	.00	-57.30	.00	-1.00	.00
249.	6	0		-41.47	.00	-57.30	.00	-57.30	.00	-1.00	.00
250.	6	0		-41.53	.00	-57.30	.00	-57.30	.00	-1.00	.00
251.	6	0	-24.35	-24.35	.14	259.82	-.16	-57.30	.00	-1.00	.00

SUBSYSTEM VALUES

BARRIER SHIP VALUES

TIME	TACTIC	SNORK	AVE S/N	S/N	PROB D	D.BEARING	D.B ERR	P.BEAR	P.B ERR	P.RANGE	P.R ERR
252.	9	0	-24.40	-24.46	.19	257.15	-.14	-57.30	.00	-1.00	.00
253.	9	0	-24.40	-24.70	.19	254.57	-.14	254.66	-.05	5954.28	-148.94
254.	9	0	-24.40	-24.81	.19	56.44	-.19	56.55	-.08	5983.56	-175.21
255.	5	0	-24.40	-24.92	.19	55.55	-.31	55.70	-.15	5957.68	-257.80
256.	5	0	-24.40	-24.92	.19	55.23	.39	54.54	-.30	5711.83	-504.56

SUBSYSTEM VALUES

				PENETRATOR SHIP VALUES				
TIME	TACTIC	SNORK	AVE S/N	S/N	PROB D	BEARING	BEAR ERR	RHO
1.	1	1		-64.95	.00	-57.30	.00	7404.29
2.	1	1		-64.48	.00	-57.30	.00	7172.26
3.	1	1		-64.01	.00	-57.30	.00	6936.28
4.	1	1		-63.53	.00	-57.30	.00	6696.57
5.	1	1		-63.05	.00	-57.30	.00	6453.36
6.	1	1		-62.65	.00	-57.30	.00	6257.04
7.	1	1		-62.34	.00	-57.30	.00	6102.80
8.	1	1		-62.09	.00	-57.30	.00	5949.36
9.	1	1		-61.94	.00	-57.30	.00	5796.78
10.	1	1		-61.78	.00	-57.30	.00	5645.12
11.	1	1		-61.57	.00	-57.30	.00	5433.09
12.	1	1		-61.36	.00	-57.30	.00	5221.08
13.	1	1		-61.15	.00	-57.30	.00	5009.11
14.	1	1		-60.53	.00	-57.30	.00	4797.18
15.	1	1		-59.90	.00	-57.30	.00	4585.29
16.	1	1		-59.45	.00	-57.30	.00	4435.82
17.	1	1		-59.00	.00	-57.30	.00	4287.80
18.	1	1		-58.56	.00	-57.30	.00	4141.39
19.	1	1		-58.13	.00	-57.30	.00	3996.75
20.	1	1		-57.70	.00	-57.30	.00	3854.08
21.	1	1		-57.09	.00	-57.30	.00	3649.49
22.	1	1		-56.48	.00	-57.30	.00	3445.43
23.	1	1		-55.87	.00	-57.30	.00	3242.01
24.	1	1		-70.49	.00	-57.30	.00	3209.30
25.	1	1		-70.46	.00	-57.30	.00	3177.08
26.	1	1		-70.42	.00	-57.30	.00	3132.63
27.	1	1		-70.37	.00	-57.30	.00	3089.25
28.	1	1		-70.33	.00	-57.30	.00	3046.97
29.	1	1		-70.29	.00	-57.30	.00	3005.84
30.	1	1		-69.55	.00	-57.30	.00	2965.92
31.	1	1		-69.39	.00	-57.30	.00	2958.35
32.	1	1		-69.23	.00	-57.30	.00	2950.90
33.	1	1		-69.07	.00	-57.30	.00	2943.56
34.	1	1		-68.92	.00	-57.30	.00	2936.35
35.	1	1		-68.76	.00	-57.30	.00	2929.25

SUBSYSTEM VALUES

PENETRATOR SHIP VALUES

TIME	TACTIC	SNORK	AVE S/N	S/N	PROB D	BEARING	BEAR ERR	RHO
36.	1	1		-69.29	.00	-57.30	.00	2953.94
37.	1	1		-69.83	.00	-57.30	.00	2978.66
38.	1	1		-70.29	.00	-57.30	.00	3003.41
39.	1	1		-70.31	.00	-57.30	.00	3028.19
40.	1	0		-70.34	.00	-57.30	.00	3052.99
41.	1	0		-55.51	.00	-57.30	.00	3041.00
42.	1	0		-55.49	.00	-57.30	.00	3029.19
43.	1	0		-55.48	.00	-57.30	.00	3017.58
44.	1	0		-55.47	.00	-57.30	.00	3006.16
45.	1	0		-55.36	.00	-57.30	.00	2994.93
46.	1	0		-55.22	.00	-57.30	.00	2988.42
47.	1	0		-55.08	.00	-57.30	.00	2982.03
48.	1	0		-54.94	.00	-57.30	.00	2975.75
49.	1	0		-54.81	.00	-57.30	.00	2969.60
50.	1	0		-54.68	.00	-57.30	.00	2963.58
51.	1	0		-54.51	.00	-57.30	.00	2955.48
52.	1	0		-54.34	.00	-57.30	.00	2947.55
53.	1	0		-54.17	.00	-57.30	.00	2939.78
54.	1	0		-54.01	.00	-57.30	.00	2932.18
55.	1	0		-53.85	.00	-57.30	.00	2924.74
56.	1	0		-53.22	.00	-57.30	.00	2895.41
57.	1	0		-52.61	.00	-57.30	.00	2867.44
58.	1	0		-52.04	.00	-57.30	.00	2840.87
59.	1	0		-51.50	.00	-57.30	.00	2815.74
60.	1	0		-50.99	.00	-57.30	.00	2792.08
61.	1	0		-51.53	.00	-57.30	.00	2816.81
62.	1	0		-52.06	.00	-57.30	.00	2841.63
63.	1	0		-52.59	.00	-57.30	.00	2866.55
64.	1	0		-53.13	.00	-57.30	.00	2891.56
65.	1	0		-53.67	.00	-57.30	.00	2916.66
66.	1	0		-53.23	.00	-57.30	.00	2896.01
67.	1	0		-52.81	.00	-57.30	.00	2876.40
68.	1	0		-52.41	.00	-57.30	.00	2857.84
69.	1	0		-52.03	.00	-57.30	.00	2840.36
70.	1	0		-51.68	.00	-57.30	.00	2823.98
71.	1	0		-51.30	.00	-57.30	.00	2806.32

SUBSYSTEM VALUES

TIME	TACTIC	SNORK	AVE S/N	PENETRATOR SHIP VALUES S/N	PROB D	BEARING	BEAR ERR	RHO
72.	1	0		-50.95	.00	-57.30	.00	2790.26
73.	1	0		-50.64	.00	-57.30	.00	2775.81
74.	1	0		-50.37	.00	-57.30	.00	2763.01
75.	1	0		-50.13	.00	-57.30	.00	2751.89
76.	1	0		-49.96	.00	-57.30	.00	2744.07
77.	1	0		-49.82	.00	-57.30	.00	2737.33
78.	1	0		-49.70	.00	-57.30	.00	2731.68
79.	1	0		-49.60	.00	-57.30	.00	2727.11
80.	1	0		-49.52	.00	-57.30	.00	2723.65
81.	1	0		-49.49	.00	-57.30	.00	2721.92
82.	1	0		-49.50	.00	-57.30	.00	2722.72
83.	1	0		-49.57	.00	-57.30	.00	2726.06
84.	1	0		-49.70	.00	-57.30	.00	2731.93
85.	1	0		-49.88	.00	-57.30	.00	2740.30
86.	1	0		-50.04	.00	-57.30	.00	2747.60
87.	1	0		-50.23	.00	-57.30	.00	2756.43
88.	1	0		-50.45	.00	-57.30	.00	2766.79
89.	1	0		-50.71	.00	-57.30	.00	2778.65
90.	1	0		-50.99	.00	-57.30	.00	2791.99
91.	1	0		-51.38	.00	-57.30	.00	2809.93
92.	1	0		-51.80	.00	-57.30	.00	2829.79
93.	1	0		-52.27	.00	-57.30	.00	2851.55
94.	1	0		-52.78	.00	-57.30	.00	2875.15
95.	1	0		-53.33	.00	-57.30	.00	2900.56
96.	1	0		-53.57	.00	-57.30	.00	2912.01
97.	1	0		-53.82	.00	-57.30	.00	2923.67
98.	1	0		-54.08	.00	-57.30	.00	2935.53
99.	1	0		-54.34	.00	-57.30	.00	2947.58
100.	1	0		-54.60	.00	-57.30	.00	2959.82
101.	1	0		-55.11	.00	-57.30	.00	2983.60
102.	1	0		-55.47	.00	-57.30	.00	3008.46
103.	1	0		-55.50	.00	-57.30	.00	3034.38
104.	1	0		-55.53	.00	-57.30	.00	3061.33
105.	1	0		-55.55	.00	-57.30	.00	3089.29
106.	1	0		-55.57	.00	-57.30	.00	3107.54
107.	1	0		-55.59	.00	-57.30	.00	3126.13

SUBSYSTEM VALUES

TIME	TACTIC	SNORK	AVE S/N	PENETRATOR SHIP VALUES S/N	PROB D	BEARING	BEAR ERR	RHO
108.	1	0		-55.61	.00	-57.30	.00	3145.05
109.	1	0		-55.63	.00	-57.30	.00	3164.30
110.	1	0		-55.65	.00	-57.30	.00	3183.86
111.	1	0		-55.70	.00	-57.30	.00	3232.29
112.	1	0		-55.75	.00	-57.30	.00	3282.47
113.	1	0		-55.80	.00	-57.30	.00	3334.34
114.	1	0		-55.85	.00	-57.30	.00	3387.81
115.	1	0		-55.91	.00	-57.30	.00	3442.81
116.	1	0		-55.94	.00	-57.30	.00	3480.14
117.	1	0		-55.98	.00	-57.30	.00	3518.16
118.	1	0		-56.02	.00	-57.30	.00	3556.85
119.	1	0		-56.06	.00	-57.30	.00	3596.19
120.	1	0		-56.10	.00	-57.30	.00	3636.15
121.	1	0		-56.11	.00	-57.30	.00	3650.12
122.	1	0		-56.13	.00	-57.30	.00	3664.11
123.	1	0		-56.14	.00	-57.30	.00	3678.13
124.	1	0		-56.16	.00	-57.30	.00	3692.17
125.	1	0		-56.17	.00	-57.30	.00	3706.23
126.	1	0		-56.17	.00	-57.30	.00	3708.29
127.	1	0		-56.17	.00	-57.30	.00	3710.42
128.	1	0		-56.18	.00	-57.30	.00	3712.62
129.	1	0		-56.18	.00	-57.30	.00	3714.89
130.	1	0		-56.18	.00	-57.30	.00	3717.24
131.	1	0		-56.24	.00	-57.30	.00	3772.32
132.	1	0		-56.29	.00	-57.30	.00	3828.42
133.	1	0		-56.35	.00	-57.30	.00	3885.48
134.	1	0		-56.41	.00	-57.30	.00	3943.47
135.	1	0		-56.47	.00	-57.30	.00	4002.34
136.	1	0		-56.48	.00	-57.30	.00	4031.54
137.	1	0		-56.49	.00	-57.30	.00	4060.94
138.	1	0		-56.51	.00	-57.30	.00	4090.54
139.	1	0		-56.52	.00	-57.30	.00	4120.32
140.	1	0		-56.54	.00	-57.30	.00	4150.29
141.	1	0		-56.54	.00	-57.30	.00	4159.38
142.	1	0		-56.55	.00	-57.30	.00	4168.46
143.	1	0		-56.55	.00	-57.30	.00	4177.55

SUBSYSTEM VALUES

PENETRATOR SHIP VALUES

TIME	TACTIC	SNORK	AVE S/N	S/N	PROB D	BEARING	BEAR ERR	RHO
144.	1	0		-56.56	.00	-57.30	.00	4186.63
145.	1	0		-56.56	.00	-57.30	.00	4195.72
146.	1	0		-56.57	.00	-57.30	.00	4208.59
147.	1	0		-56.57	.00	-57.30	.00	4221.47
148.	1	0		-56.58	.00	-57.30	.00	4234.36
149.	1	0		-56.59	.00	-57.30	.00	4247.25
150.	1	0		-56.59	.00	-57.30	.00	4260.15
151.	1	0		-56.63	.00	-57.30	.00	4322.04
152.	1	0		-56.66	.00	-57.30	.00	4384.62
153.	1	0		-56.69	.00	-57.30	.00	4447.88
154.	1	0		-56.72	.00	-57.30	.00	4511.78
155.	1	0		-56.75	.00	-57.30	.00	4576.30
156.	1	0		-56.77	.00	-57.30	.00	4603.21
157.	1	0		-56.78	.00	-57.30	.00	4630.21
158.	1	0		-56.79	.00	-57.30	.00	4657.30
159.	1	0		-56.81	.00	-57.30	.00	4684.48
160.	1	0		-56.82	.00	-57.30	.00	4711.74
161.	1	0		-56.84	.00	-57.30	.00	4754.78
162.	1	0		-56.86	.00	-57.30	.00	4798.07
163.	1	0		-56.88	.00	-57.30	.00	4841.59
164.	1	0		-56.91	.00	-57.30	.00	4885.34
165.	1	0		-56.93	.00	-57.30	.00	4929.31
166.	1	0		-56.94	.00	-57.30	.00	4945.01
167.	1	0		-56.94	.00	-57.30	.00	4960.73
168.	1	0		-56.95	.00	-57.30	.00	4976.45
169.	1	0		-56.96	.00	-57.30	.00	4992.19
170.	1	0		-56.97	.00	-57.30	.00	5007.92
171.	1	0		-57.06	.00	-57.30	.00	5095.20
172.	1	0		-57.15	.00	-57.30	.00	5183.09
173.	1	0		-57.24	.00	-57.30	.00	5271.58
174.	1	0		-57.32	.00	-57.30	.00	5360.63
175.	1	0		-57.41	.00	-57.30	.00	5450.21
176.	1	0		-57.40	.00	-57.30	.00	5437.91
177.	1	0		-57.39	.00	-57.30	.00	5425.79
178.	1	0		-57.38	.00	-57.30	.00	5413.84
179.	1	0		-57.37	.00	-57.30	.00	5402.08

SUBSYSTEM VALUES

TIME	TACTIC	SNORK	AVE S/N	PENETRATOR SHIP VALUES S/N	PROB D	BEARING	BEAR ERR	RHO
180.	1	0		-57.35	.00	-57.30	.00	5390.50
181.	1	0		-57.41	.00	-57.30	.00	5444.41
182.	1	0		-57.46	.00	-57.30	.00	5498.58
183.	1	0		-57.52	.00	-57.30	.00	5553.00
184.	1	0		-57.57	.00	-57.30	.00	5607.64
185.	1	0		-57.63	.00	-57.30	.00	5662.52
186.	1	0		-57.63	.00	-57.30	.00	5662.19
187.	1	0		-57.63	.00	-57.30	.00	5661.89
188.	1	0		-57.63	.00	-57.30	.00	5661.63
189.	1	0		-57.63	.00	-57.30	.00	5661.39
190.	1	0		-57.63	.00	-57.30	.00	5661.19
191.	1	0		-57.64	.00	-57.30	.00	5672.33
192.	1	0		-57.65	.00	-57.30	.00	5683.47
193.	1	0		-57.66	.00	-57.30	.00	5694.61
194.	1	0		-57.67	.00	-57.30	.00	5705.75
195.	1	0		-57.68	.00	-57.30	.00	5716.89
196.	1	0		-57.71	.00	-57.30	.00	5745.81
197.	1	0		-57.74	.00	-57.30	.00	5774.77
198.	1	0		-57.77	.00	-57.30	.00	5803.79
199.	1	0		-57.80	.00	-57.30	.00	5832.86
200.	1	0		-57.83	.00	-57.30	.00	5861.98
201.	1	0		-57.81	.00	-57.30	.00	5849.45
202.	1	0		-57.80	.00	-57.30	.00	5837.09
203.	1	0		-57.79	.00	-57.30	.00	5824.89
204.	1	0		-57.78	.00	-57.30	.00	5812.86
205.	1	0		-57.77	.00	-57.30	.00	5800.99
206.	1	0		-57.85	.00	-57.30	.00	5883.47
207.	1	0		-57.93	.00	-57.30	.00	5966.40
208.	1	0		-57.99	.00	-57.30	.00	6049.75
209.	1	0		-58.03	.00	-57.30	.00	6133.51
210.	1	0		-58.07	.00	-57.30	.00	6217.65
211.	1	0		-58.09	.00	-57.30	.00	6255.51
212.	1	0		-58.11	.00	-57.30	.00	6293.45
213.	1	0		-58.13	.00	-57.30	.00	6331.47
214.	1	0		-58.15	.00	-57.30	.00	6369.57
215.	1	0		-58.17	.00	-57.30	.00	6407.75

SUBSYSTEM VALUES

				PENETRATOR SHIP VALUES				
TIME	TACTIC	SNORK	AVE S/N	S/N	PROB D	BEARING	BEAR ERR	RHO
216.	1	0		-58.13	.00	-57.30	.00	6426.59
217.	1	0		-58.19	.00	-57.30	.00	6445.44
218.	1	0		-58.20	.00	-57.30	.00	6464.30
219.	1	0		-58.21	.00	-57.30	.00	6483.16
220.	1	0		-58.22	.00	-57.30	.00	6502.03
221.	1	0		-58.25	.00	-57.30	.00	6577.69
222.	1	0		-58.29	.00	-57.30	.00	6653.62
223.	1	0		-58.33	.00	-57.30	.00	6729.81
224.	1	0		-58.37	.00	-57.30	.00	6806.25
225.	1	0		-58.41	.00	-57.30	.00	6882.93
226.	1	0		-58.43	.00	-57.30	.00	6921.96
227.	1	0		-58.44	.00	-57.30	.00	6961.05
228.	1	0		-58.46	.00	-57.30	.00	7000.20
229.	1	0		-58.50	.00	-57.30	.00	7039.42
230.	1	0		-58.54	.00	-57.30	.00	7078.69
231.	1	0		-58.60	.00	-57.30	.00	7133.43
232.	1	0		-58.65	.00	-57.30	.00	7188.30
233.	1	0		-49.39	.00	-57.30	.00	7035.88
234.	1	0		-49.11	.00	-57.30	.00	6893.32
235.	1	0		-48.84	.00	-57.30	.00	6761.24
236.	1	0		-48.49	.00	-57.30	.00	6583.65
237.	1	0		-48.15	.00	-57.30	.00	6415.55
238.	1	0		-47.83	.00	-57.30	.00	6257.70
239.	1	0		-47.54	.00	-57.30	.00	6110.89
240.	1	0		-47.29	.00	-57.30	.00	5975.95
241.	1	0		-47.19	.00	-57.30	.00	5873.56
242.	1	0		-47.10	.00	-57.30	.00	5785.35
243.	1	0		-47.03	.00	-57.30	.00	5711.97
244.	1	0		-46.97	.00	-57.30	.00	5654.00
245.	1	0		-46.93	.00	-57.30	.00	5611.93
246.	1	0		-46.93	.00	-57.30	.00	5607.32
247.	1	0		-46.94	.00	-57.30	.00	5619.10
248.	1	0		-46.97	.00	-57.30	.00	5647.17
249.	1	0		-47.01	.00	-57.30	.00	5691.29
250.	1	1		-47.07	.00	-57.30	.00	5751.10
251.	1	1		-61.99	.00	-57.30	.00	5855.37

SUBSYSTEM VALUES

TIME	TACTIC	SNORK	AVE S/N	PENETRATOR S/N	PENETRATOR PROB D	SHIP VALUES BEARING	SHIP VALUES BEAR ERR	SHIP VALUES RHO
252.	1	1		-62.11	.00	-57.30	.00	5973.00
253.	1	1		-62.35	.00	-57.30	.00	6103.22
254.	1	1		-62.46	.00	-57.30	.00	6158.77
255.	1	1		-62.57	.00	-57.30	.00	6215.47
256.	1	1		-62.57	.00	-57.30	.00	6216.39

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SUBSYSTEM VALUES

BARRIER SHIP VALUES
TRACKING INFORMATION

TIME	X(EST.)	Y(EST.)	SPEED(EST)	TRACKING FLAGS DIST	X	Y	XVEL(EST)	YVEL(EST)	SIGMA X	SIGMA Y
7.	29173.11	83152.45	.00	1	0	0	.00	.00	.00	.00
8.	29375.75	83119.62	6.08	2	0	0	6.00	-.97	.00	.00
9.	29150.29	82478.63	11.88	3	0	0	-1.60	-11.77	209.76	297.62
10.	29167.04	82292.24	9.12	4	0	0	-.70	-9.09	153.36	240.00
11.	29197.67	82137.67	7.59	5	0	0	-.17	-7.59	129.45	217.03
12.	29215.04	81974.[illegible]	6.33	6	0	0	.02	-6.83	113.28	197.91
13.	29214.44	81795.25	6.48	7	0	0	.01	-6.48	101.13	180.45
14.	29193.95	81596.46	6.36	8	0	0	-.11	-6.36	93.69	165.51
15.	29169.06	81355.66	6.50	9	0	0	-.22	-6.50	88.26	154.65
16.	29280.44	81275.29	5.86	10	0	0	.33	-5.85	128.56	184.87
17.	29342.87	81120.52	5.69	11	0	0	.55	-5.67	129.00	178.81
18.	29379.50	80928.25	5.70	12	0	0	.62	-5.67	123.52	168.72
19.	29386.78	80680.71	5.90	13	0	0	.57	-5.87	118.51	169.05
20.	29466.68	80517.24	5.81	14	0	0	.77	-5.75	127.71	166.02
21.	29497.02	80305.17	5.86	15	0	0	.78	-5.81	122.74	160.74
22.	29546.71	80133.18	5.80	16	1	1	.85	-5.74	120.76	157.23
23.	29548.19	79914.65	5.86	17	1	1	.78	-5.81	120.12	153.91
24.	29574.42	79718.54	5.86	17	1	1	.78	-5.81	120.12	153.91
25.	29600.65	79522.42	5.86	17	1	1	.78	-5.81	120.12	153.91
26.	29626.88	79326.30	5.86	17	1	1	.78	-5.81	120.12	153.91
27.	29653.11	79130.18	5.86	17	1	1	.78	-5.81	120.12	153.91
28.	29679.34	78934.06	5.86	17	1	1	.78	-5.81	120.12	153.91
29.	29705.57	78737.94	5.86	17	1	1	.78	-5.81	120.12	153.91
30.	29731.80	78541.82	5.86	17	1	1	.78	-5.81	120.12	153.91
31.	29758.03	78345.70	5.86	17	1	1	.78	-5.81	120.12	153.91
32.	29784.26	78149.59	5.86	17	1	1	.78	-5.81	120.12	153.91
33.	29810.49	77953.47	5.86	17	1	1	.78	-5.81	120.12	153.91
34.	29836.72	77757.35	5.86	17	1	1	.78	-5.81	120.12	153.91
35.	29862.94	77561.23	5.86	17	1	1	.78	-5.81	120.12	153.91
36.	29889.17	77365.11	5.86	17	1	1	.78	-5.81	120.12	153.91
37.	29915.40	77168.99	5.86	17	1	1	.78	-5.81	120.12	153.91
38.	29941.63	76972.87	5.86	17	1	1	.78	-5.81	120.12	153.91
39.	29967.86	76776.75	5.86	17	1	1	.78	-5.81	120.12	153.91
40.	29994.09	76580.63	5.86	17	1	1	.78	-5.81	120.12	153.91
41.	30020.32	76384.52	5.86	17	1	1	.78	-5.81	120.12	153.91

SUBSYSTEM VALUES

BARRIER SHIP VALUES

TIME	X(EST.)	Y(EST.)	SPEED(EST)	TRACKING INFORMATION TRACKING DIST	FLAGS X	FLAGS Y	XVFL(EST)	YVEL(EST)	SIGMA X	SIGMA Y
42.	30046.55	76188.40	5.86	17	1	1	.78	-5.81	120.12	153.91
43.	30072.78	75992.28	5.86	17	1	1	.78	-5.81	120.12	153.91
44.	30099.01	75796.16	5.86	17	1	1	.78	-5.81	120.12	153.91
45.	30125.24	75600.04	5.86	17	1	1	.78	-5.81	120.12	153.91
46.	30151.47	75403.92	5.86	17	1	1	.78	-5.81	120.12	153.91
47.	30177.70	75207.80	5.86	17	1	1	.78	-5.81	120.12	153.91
48.	30203.93	75011.68	5.86	17	1	1	.78	-5.81	120.12	153.91
49.	30230.16	74815.57	5.86	17	1	1	.78	-5.81	120.12	153.91
50.	30256.39	74619.45	5.86	17	1	1	.78	-5.81	120.12	153.91
51.	30282.62	74423.33	5.86	17	1	1	.78	-5.81	120.12	153.91
52.	30308.85	74227.21	5.86	17	1	1	.78	-5.81	120.12	153.91
53.	30335.08	74031.09	5.86	17	1	1	.78	-5.81	120.12	153.91
54.	30361.31	73834.97	5.86	17	1	1	.78	-5.81	120.12	153.91
55.	30387.53	73638.85	5.86	17	1	1	.78	-5.81	120.12	153.91
56.	30413.76	73442.74	5.86	17	1	1	.78	-5.81	120.12	153.91
57.	30439.99	73246.62	5.86	17	1	1	.78	-5.81	120.12	153.91
58.	30466.22	73050.50	5.86	17	1	1	.78	-5.81	120.12	153.91
59.	30492.45	72854.38	5.86	17	1	1	.78	-5.81	120.12	153.91
60.	30518.68	72658.26	5.86	17	1	1	.78	-5.81	120.12	153.91
61.	30544.91	72462.14	5.86	17	1	1	.78	-5.81	120.12	153.91
62.	30571.14	72266.02	5.86	17	1	1	.78	-5.81	120.12	153.91
63.	30597.37	72069.90	5.86	17	1	1	.78	-5.81	120.12	153.91
64.	30623.60	71873.79	5.86	17	1	1	.78	-5.81	120.12	153.91
65.	30649.83	71677.67	5.86	17	1	1	.78	-5.81	120.12	153.91
66.	30676.06	71481.55	5.86	17	1	1	.78	-5.81	120.12	153.91
67.	30702.29	71285.43	5.86	17	1	1	.78	-5.81	120.12	153.91
68.	30728.52	71089.31	5.86	17	1	1	.78	-5.81	120.12	153.91
69.	30754.75	70893.19	5.86	17	1	1	.78	-5.81	120.12	153.91
70.	30780.98	70697.07	5.86	17	1	1	.78	-5.81	120.12	153.91
71.	30807.21	70500.95	5.86	17	1	1	.78	-5.81	120.12	153.91
72.	30833.44	70304.84	5.86	17	1	1	.78	-5.81	120.12	153.91
73.	30859.67	70108.72	5.86	17	1	1	.78	-5.81	120.12	153.91
74.	30885.90	69912.60	5.86	17	1	1	.78	-5.81	120.12	153.91
75.	30912.13	69716.48	5.86	17	1	1	.78	-5.81	120.12	153.91
76.	30938.36	69520.36	5.86	17	1	1	.78	-5.81	120.12	153.91

SUBSYSTEM VALUES

BARRIER SHIP VALUES
TRACKING INFORMATION

TIME	X(EST.)	Y(EST.)	SPEED(EST)	TRACKING DIST	FLAGS X	FLAGS Y	XVEL(EST)	YVEL(EST)	SIGMA X	SIGMA Y
77.	30964.58	69324.24	5.86	17	1	1	.78	-5.81	120.12	153.91
78.	30990.81	69128.13	5.86	17	1	1	.78	-5.81	120.12	153.91
79.	31017.04	68932.01	5.86	17	1	1	.78	-5.81	120.12	153.91
80.	31043.27	68735.89	5.86	17	1	1	.78	-5.81	120.12	153.91
81.	31069.50	68539.77	5.86	17	1	1	.78	-5.81	120.12	153.91
82.	31095.73	68343.65	5.86	17	1	1	.78	-5.81	120.12	153.91
83.	31121.96	68147.53	5.86	17	1	1	.78	-5.81	120.12	153.91
84.	31148.19	67951.41	5.86	17	1	1	.78	-5.81	120.12	153.91
85.	31174.42	67755.29	5.86	17	1	1	.78	-5.81	120.12	153.91
86.	31200.65	67559.18	5.86	17	1	1	.78	-5.81	120.12	153.91
87.	31226.88	67363.06	5.86	17	1	1	.78	-5.81	120.12	153.91
88.	31253.11	67166.94	5.86	17	1	1	.78	-5.81	120.12	153.91
89.	31279.34	66970.82	5.86	17	1	1	.78	-5.81	120.12	153.91
90.	31305.57	66774.70	5.86	17	1	1	.78	-5.81	120.12	153.91
91.	31331.80	66578.58	5.86	17	1	1	.78	-5.81	120.12	153.91
92.	31358.03	66382.46	5.86	17	1	1	.78	-5.81	120.12	153.91
93.	31384.26	66186.35	5.86	17	1	1	.78	-5.81	120.12	153.91
94.	31410.49	65990.23	5.86	17	1	1	.78	-5.81	120.12	153.91
95.	31436.72	65794.11	5.86	17	1	1	.78	-5.81	120.12	153.91
96.	31462.95	65597.99	5.86	17	1	1	.78	-5.81	120.12	153.91
97.	31489.17	65401.87	5.86	17	1	1	.78	-5.81	120.12	153.91
98.	31515.40	65205.75	5.86	17	1	1	.78	-5.81	120.12	153.91
99.	31541.63	65009.63	5.86	17	1	1	.78	-5.81	120.12	153.91
100.	31567.86	64813.52	5.86	17	1	1	.78	-5.81	120.12	153.91
101.	31594.09	64617.40	5.86	17	1	1	.78	-5.81	120.12	153.91
102.	31620.32	64421.28	5.86	17	1	1	.78	-5.81	120.12	153.91
103.	31646.55	64225.16	5.86	17	1	1	.78	-5.81	120.12	153.91
104.	31672.78	64029.04	5.86	17	1	1	.78	-5.81	120.12	153.91
105.	31699.01	63832.92	5.86	17	1	1	.78	-5.81	120.12	153.91
106.	31725.24	63636.81	5.86	17	1	1	.78	-5.81	120.12	153.91
107.	31751.47	63440.69	5.86	17	1	1	.78	-5.81	120.12	153.91
108.	31777.70	63244.57	5.86	17	1	1	.78	-5.81	120.12	153.91
109.	31803.93	63048.45	5.86	17	1	1	.78	-5.81	120.12	153.91
110.	31830.16	62852.33	5.86	17	1	1	.78	-5.81	120.12	153.91
111.	31856.39	62656.21	5.86	17	1	[illegible]	.78	-5.81	120.12	153.91

SUBSYSTEM VALUES

BARRIER SHIP VALUES

TRACKING INFORMATION

TIME	X(EST.)	Y(EST.)	SPEED(EST)	TRACKING DIST	FLAGS X	FLAGS Y	XVEL(EST)	YVEL(EST)	SIGMA X	SIGMA Y
112.	31882.62	62460.09	5.86	17	1	1	.78	-5.81	120.12	153.91
113.	31908.85	62263.98	5.86	17	1	1	.78	-5.81	120.12	153.91
114.	31935.08	62067.86	5.86	17	1	1	.78	-5.81	120.12	153.91
115.	31961.31	61871.74	5.86	17	1	1	.78	-5.81	120.12	153.91
116.	31987.54	61675.62	5.86	17	1	1	.78	-5.81	120.12	153.91
117.	32013.76	61479.50	5.86	17	1	1	.78	-5.81	120.12	153.91
118.	32039.99	61283.38	5.86	17	1	1	.78	-5.81	120.12	153.91
119.	32066.22	61087.26	5.86	17	1	1	.78	-5.81	120.12	153.91
120.	32092.45	60891.15	5.86	17	1	1	.78	-5.81	120.12	153.91
121.	32118.68	60695.03	5.86	17	1	1	.78	-5.81	120.12	153.91
122.	32144.91	60498.91	5.86	17	1	1	.78	-5.81	120.12	153.91
123.	32171.14	60302.79	5.86	17	1	1	.78	-5.81	120.12	153.91
124.	32197.37	60106.67	5.86	17	1	1	.78	-5.81	120.12	153.91
125.	32223.60	59910.56	5.86	17	1	1	.78	-5.81	120.12	153.91
126.	32249.83	59714.44	5.86	17	1	1	.78	-5.81	120.12	153.91
127.	32276.06	59518.32	5.86	17	1	1	.78	-5.81	120.12	153.91
128.	32302.29	59322.20	5.86	17	1	1	.78	-5.81	120.12	153.91
129.	32328.52	59126.08	5.86	17	1	1	.78	-5.81	120.12	153.91
130.	32354.75	58929.96	5.86	17	1	1	.78	-5.81	120.12	153.91
131.	32380.98	58733.84	5.86	17	1	1	.78	-5.81	120.12	153.91
132.	32407.21	58537.73	5.86	17	1	1	.78	-5.81	120.12	153.91
133.	32433.44	58341.61	5.86	17	1	1	.78	-5.81	120.12	153.91
134.	32459.67	58145.49	5.86	17	1	1	.78	-5.81	120.12	153.91
135.	32485.90	57949.37	5.86	17	1	1	.78	-5.81	120.12	153.91
136.	32512.13	57753.25	5.86	17	1	1	.78	-5.81	120.12	153.91
137.	32538.36	57557.13	5.86	17	1	1	.78	-5.81	120.12	153.91
138.	32564.58	57361.02	5.86	17	1	1	.78	-5.81	120.12	153.91
139.	32590.81	57164.90	5.86	17	1	1	.78	-5.81	120.12	153.91
140.	32617.04	56968.78	5.86	17	1	1	.78	-5.81	120.12	153.91
141.	32643.27	56772.66	5.86	17	1	1	.78	-5.81	120.12	153.91
142.	32669.50	56576.54	5.86	17	1	1	.78	-5.81	120.12	153.91
143.	32695.73	56380.42	5.86	17	1	1	.78	-5.81	120.12	153.91
144.	32721.96	56184.31	5.86	17	1	1	.78	-5.81	120.12	153.91
145.	32748.19	55988.19	5.86	17	1	1	.78	-5.81	120.12	153.91
146.	32774.42	55792.07	5.86	17	1	1	.78	-5.81	120.12	153.91

SUBSYSTEM VALUES

BARRIER SHIP VALUES

TRACKING INFORMATION

TIME	X(EST.)	Y(EST.)	SPEED(EST)	TRACKING DIST	FLAGS X	FLAGS Y	XVEL(EST)	YVEL(EST)	SIGMA X	SIGMA Y
147.	32800.65	55595.95	5.86	17	1	1	.78	-5.81	120.12	153.91
148.	32826.88	55399.83	5.86	17	1	1	.78	-5.81	120.12	153.91
149.	32853.11	55203.71	5.86	17	1	1	.78	-5.81	120.12	153.91
150.	32879.34	55007.59	5.86	17	1	1	.78	-5.81	120.12	153.91
151.	32905.57	54811.48	5.86	17	1	1	.78	-5.81	120.12	153.91
152.	32931.80	54615.36	5.86	17	1	1	.78	-5.81	120.12	153.91
153.	32958.03	54419.24	5.86	17	1	1	.78	-5.81	120.12	153.91
154.	32984.26	54223.12	5.86	17	1	1	.78	-5.81	120.12	153.91
155.	33010.49	54027.00	5.86	17	1	1	.78	-5.81	120.12	153.91
156.	33036.71	53830.89	5.86	17	1	1	.78	-5.81	120.12	153.91
157.	33062.94	53634.77	5.86	17	1	1	.78	-5.81	120.12	153.91
158.	33089.17	53438.65	5.86	17	1	1	.78	-5.81	120.12	153.91
159.	33115.40	53242.53	5.86	17	1	1	.78	-5.81	120.12	153.91
160.	33141.63	53046.41	5.86	17	1	1	.78	-5.81	120.12	153.91
161.	33167.86	52850.29	5.86	17	1	1	.78	-5.81	120.12	153.91
162.	33194.09	52654.18	5.86	17	1	1	.78	-5.81	120.12	153.91
163.	33220.32	52458.06	5.86	17	1	1	.78	-5.81	120.12	153.91
164.	33246.55	52261.94	5.86	17	1	1	.78	-5.81	120.12	153.91
165.	33272.78	52065.82	5.86	17	1	1	.78	-5.81	120.12	153.91
166.	33299.01	51869.70	5.86	17	1	1	.78	-5.81	120.12	153.91
167.	33325.24	51673.58	5.86	17	1	1	.78	-5.81	120.12	153.91
168.	33351.47	51477.47	5.86	17	1	1	.78	-5.81	120.12	153.91
169.	33377.70	51281.35	5.86	17	1	1	.78	-5.81	120.12	153.91
170.	33403.93	51085.23	5.86	17	1	1	.78	-5.81	120.12	153.91
171.	33430.16	50889.11	5.86	17	1	1	.78	-5.81	120.12	153.91
172.	33456.39	50692.99	5.86	17	1	1	.78	-5.81	120.12	153.91
173.	33482.62	50496.87	5.86	17	1	1	.78	-5.81	120.12	153.91
174.	33508.85	50300.76	5.86	17	1	1	.78	-5.81	120.12	153.91
175.	33535.08	50104.64	5.86	17	1	1	.78	-5.81	120.12	153.91
176.	33561.30	49908.52	5.86	17	1	1	.78	-5.81	120.12	153.91
177.	33587.53	49712.40	5.86	17	1	1	.78	-5.81	120.12	153.91
178.	33613.76	49516.28	5.86	17	1	1	.78	-5.81	120.12	153.91
179.	33639.99	49320.17	5.86	17	1	1	.78	-5.81	120.12	153.91
180.	33666.22	49124.05	5.86	17	1	1	.78	-5.81	120.12	153.91
181.	33692.45	48927.93	5.86	17	1	1	.78	-5.81	120.12	153.91

SUBSYSTEM VALUES

BARRIER SHIP VALUES

TIME	X(EST.)	Y(EST.)	SPEED(EST)	TRACKING INFORMATION TRACKING DIST	FLAGS X	FLAGS Y	XVEL(EST)	YVEL(EST)	SIGMA X	SIGMA Y
182.	33718.68	48731.81	5.86	17	1	1	.78	-5.81	120.12	153.91
183.	33744.91	48535.69	5.86	17	1	1	.78	-5.81	120.12	153.91
184.	33771.14	48339.57	5.86	17	1	1	.78	-5.81	120.12	153.91
185.	33797.37	48143.46	5.86	17	1	1	.78	-5.81	120.12	153.91
186.	33823.60	47947.34	5.86	17	1	1	.78	-5.81	120.12	153.91
187.	33849.83	47751.22	5.86	17	1	1	.78	-5.81	120.12	153.91
188.	33876.06	47555.10	5.86	17	1	1	.78	-5.81	120.12	153.91
189.	33902.29	47358.98	5.86	17	1	1	.78	-5.81	120.12	153.91
190.	33928.52	47162.87	5.86	17	1	1	.78	-5.81	120.12	153.91
191.	33954.75	46966.75	5.86	17	1	1	.78	-5.81	120.12	153.91
192.	33980.98	46770.63	5.86	17	1	1	.78	-5.81	120.12	153.91
193.	34007.21	46574.51	5.86	17	1	1	.78	-5.81	120.12	153.91
194.	34033.43	46378.39	5.86	17	1	1	.78	-5.81	120.12	153.91
195.	34059.66	46182.28	5.86	17	1	1	.78	-5.81	120.12	153.91
196.	34085.89	45986.16	5.86	17	1	1	.78	-5.81	120.12	153.91
197.	34112.12	45790.04	5.86	17	1	1	.78	-5.81	120.12	153.91
198.	34138.35	45593.92	5.86	17	1	1	.78	-5.81	120.12	153.91
199.	34164.58	45397.80	5.86	17	1	1	.78	-5.81	120.12	153.91
200.	34190.81	45201.68	5.86	17	1	1	.78	-5.81	120.12	153.91
201.	34217.04	45005.57	5.86	17	1	1	.78	-5.81	120.12	153.91
202.	34243.27	44809.45	5.86	17	1	1	.78	-5.81	120.12	153.91
203.	34269.50	44613.33	5.86	17	1	1	.78	-5.81	120.12	153.91
204.	34295.73	44417.21	5.86	17	1	1	.78	-5.81	120.12	153.91
205.	34321.96	44221.09	5.86	17	1	1	.78	-5.81	120.12	153.91
206.	34348.19	44024.98	5.86	17	1	1	.78	-5.81	120.12	153.91
207.	34374.42	43828.86	5.86	17	1	1	.78	-5.81	120.12	153.91
208.	34400.65	43632.74	5.86	17	1	1	.78	-5.81	120.12	153.91
209.	34426.88	43436.62	5.86	17	1	1	.78	-5.81	120.12	153.91
210.	34453.11	43240.50	5.86	17	1	1	.78	-5.81	120.12	153.91
211.	34479.34	43044.38	5.86	17	1	1	.78	-5.81	120.12	153.91
212.	34505.56	42848.27	5.86	17	1	1	.78	-5.81	120.12	153.91
213.	34531.79	42652.15	5.86	17	1	1	.78	-5.81	120.12	153.91
214.	34558.02	42456.03	5.86	17	1	1	.78	-5.81	120.12	153.91
215.	34584.25	42259.91	5.86	17	1	1	.78	-5.81	120.12	153.91
216.	34610.48	42063.80	5.86	17	1	1	.78	-5.81	120.12	153.91

SUBSYSTEM VALUES

BARRIER SHIP VALUES

TIME	X(EST.)	Y(EST.)	SPEED(EST)	TRACKING INFORMATION TRACKING DIST	FLAGS X	FLAGS Y	XVEL(EST)	YVEL(EST)	SIGMA X	SIGMA Y
217.	34636.71	41867.68	5.86	17	1	1	.78	-5.81	120.12	153.91
218.	34662.94	41671.56	5.86	17	1	1	.78	-5.81	120.12	153.91
219.	34689.17	41475.44	5.86	17	1	1	.78	-5.81	120.12	153.91
220.	34715.40	41279.32	5.86	17	1	1	.78	-5.81	120.12	153.91
221.	34741.63	41083.20	5.86	17	1	1	.78	-5.81	120.12	153.91
222.	34767.86	40887.09	5.86	17	1	1	.78	-5.81	120.12	153.91
223.	34794.09	40690.97	5.86	17	1	1	.78	-5.81	120.12	153.91
224.	34820.32	40494.85	5.86	17	1	1	.78	-5.81	120.12	153.91
225.	34846.55	40298.73	5.86	17	1	1	.78	-5.81	120.12	153.91
226.	34872.78	40102.61	5.86	17	1	1	.78	-5.81	120.12	153.91
227.	34899.01	39906.50	5.86	17	1	1	.78	-5.81	120.12	153.91
228.	34925.24	39710.38	5.86	17	1	1	.78	-5.81	120.12	153.91
229.	34951.47	39514.26	5.86	17	1	1	.78	-5.81	120.12	153.91
230.	34977.69	39318.14	5.86	17	1	1	.78	-5.81	120.12	153.91
231.	35003.92	39122.02	5.86	17	1	1	.78	-5.81	120.12	153.91
232.	35030.15	38925.91	5.86	17	1	1	.78	-5.81	120.12	153.91
233.	35056.38	38729.79	5.86	17	1	1	.78	-5.81	120.12	153.91
234.	35082.61	38533.67	5.86	17	1	1	.78	-5.81	120.12	153.91
235.	35108.84	38337.55	5.86	17	1	1	.78	-5.81	120.12	153.91
236.	35135.07	38141.43	5.86	17	1	1	.78	-5.81	120.12	153.91
237.	35161.30	37945.32	5.86	17	1	1	.78	-5.81	120.12	153.91
238.	35187.53	37749.20	5.86	17	1	1	.78	-5.81	120.12	153.91
239.	35213.76	37553.08	5.86	17	1	1	.78	-5.81	120.12	153.91
240.	35239.99	37356.96	5.86	17	1	1	.78	-5.81	120.12	153.91
241.	35266.22	37160.84	5.86	17	1	1	.78	-5.81	120.12	153.91
242.	35292.45	36964.73	5.86	17	1	1	.78	-5.81	120.12	153.91
243.	35318.68	36768.61	5.86	17	1	1	.78	-5.81	120.12	153.91
244.	35344.91	36572.49	5.86	17	1	1	.78	-5.81	120.12	153.91
245.	35371.14	36376.37	5.86	17	1	1	.78	-5.81	120.12	153.91
246.	35397.37	36180.25	5.86	17	1	1	.78	-5.81	120.12	153.91
247.	35423.60	35984.14	5.86	17	1	1	.78	-5.81	120.12	153.91
248.	35449.82	35788.02	5.86	17	1	1	.78	-5.81	120.12	153.91
249.	35476.05	35591.90	5.86	17	1	1	.78	-5.81	120.12	153.91
250.	35502.28	35395.78	5.86	17	1	1	.78	-5.81	120.12	153.91
251.	35528.51	35199.67	5.86	17	1	1	.78	-5.81	120.12	153.91

UNCLASSIFIED

SUBSYSTEM VALUES

BARRIER SHIP VALUES
TRACKING INFORMATION

TIME	X(EST.)	Y(EST.)	SPEED(EST)	TRACKING DIST	FLAGS X	FLAGS Y	XVEL(EST)	YVEL(EST)	SIGMA X	SIGMA Y
253.	29970.12	34106.09	.00	1	0	0	.00	.00	.00	.00
254.	29962.80	33915.98	5.63	2	0	0	-.22	-5.63	.00	.00
255.	29999.19	33743.32	5.35	3	0	0	.56	-5.32	19.60	9.80
256.	30191.12	33622.60	5.34	4	0	0	2.75	-4.57	96.83	33.94

SUBSYSTEM VALUES

BARRIER SHIP VALUES
FIRE CONTROL INFORMATION

TIME	X(EST.)	Y(EST.)	SPEED(EST)	TRACKING DIST	FLAGS X	FLAGS Y	XVFL(EST)	YVEL(EST)	SIGMA X	SIGMA Y
7.	29173.11	83152.45	.00	1	0	0	.00	.00	.00	.00
8.	29375.75	83119.62	6.08	2	0	0	6.00	-.97	.00	.00
9.	29150.29	82478.83	11.88	3	1	0	-1.60	-11.77	209.76	297.62
10.	29167.04	82292.24	9.12	4	1	1	-.70	-9.09	153.36	240.00
11.	29197.67	82137.67	7.59	5	1	1	-.17	-7.59	129.45	217.03
12.	29215.04	81974.90	6.83	6	1	1	.02	-6.83	113.28	197.91
13.	29214.44	81795.25	6.48	7	1	1	.01	-6.48	101.13	180.45
14.	29193.95	81596.46	6.36	8	1	1	-.11	-6.36	93.69	165.51
15.	29169.06	81355.66	6.50	9	1	1	-.22	-6.50	88.26	154.65
16.	29280.44	81275.29	5.86	10	1	1	.33	-5.85	128.56	184.87
17.	29342.87	81120.52	5.69	11	1	1	.55	-5.67	129.00	178.81
18.	29379.50	80928.25	5.70	12	1	1	.62	-5.67	123.52	168.72
19.	29386.78	80680.71	5.90	13	1	1	.57	-5.87	118.51	169.05
20.	29466.68	80517.24	5.81	14	1	1	.77	-5.75	127.71	166.02
21.	29497.02	80305.17	5.86	15	1	1	.78	-5.81	122.74	160.74
22.	29546.71	80133.18	5.80	16	1	1	.85	-5.74	120.76	157.23
23.	29548.19	79914.65	5.86	17	1	0	.78	-5.81	120.12	153.91
253.	29970.12	34106.09	.00	1	0	0	.00	.00	.00	.00
254.	29962.80	33915.98	5.63	2	0	0	-.22	-5.63	.00	.00
255.	29999.19	33743.32	5.35	3	1	1	.56	-5.32	19.60	9.80
256.	30191.12	33622.60	5.34	4	1	1	2.75	-4.57	96.83	33.94

TRACOR 6500 TRACOR LANE, AUSTIN, TEXAS 78721

A.2 POSIT

PURPOSE: This subroutine computes new position and velocity coordinates for each boat as well as computing the range, true bearing, heading, relative bearing, and other data used in the program. The subroutine first integrates the equations of motion for each boat, then computes the required data.

INPUT:

TIME = Time

DELT = Length of time step (min)

NBOAT = Number of boats in the simulation

MOTION = Array describing the type of motion which each boat is effecting
- 1 = Straight line path, constant velocity
- 2 = Straight line path, constant acceleration
- 3 = Circular path, constant speed

BS(I,IBOAT) = Array of motion parameters for each boat IBOAT

- I = 1 Horizontal linear speed (kts)
- I = 2 Heading (degrees)
- I = 3 Horizontal circular speed (kts)
- I = 4 Radius of circular motion (yds)
- I = 5 X-coordinate of center of circle (yds)
- I = 6 Y-coordinate of center of circle (yds)
- I = 7 Horizontal linear acceleration (kts/min)

OUTPUT:

RDOT(J,IBOAT) = J-component of IBOAT's velocity vector (kts)

R(J,IBOAT) = A three component vector which defines the current position (X,Y,Z) of boat IBOAT (yds)

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RDDOT(J,IBOAT) = Three component vector defining the linear acceleration of boat IBOAT (kts/min)

RHO = Range between IBOAT and JBOAT (yds)

PHIRHO = True bearing of JBOAT from IBOAT (radians)

RELB = Relative bearing of JBOAT from IBOAT (radians)

INTERNAL VARIABLES AND ARBITRARY CONSTANTS:

PSI = Angle which radius vector to IBOAT makes with North, in a clockwise sense, at the beginning of the time step (radians)

ARGC = Angle which radius vector to IBOAT makes with North, in a clockwise sense, at the end of the time step (radians)

Conversion from knots to yards per minute = 33.783

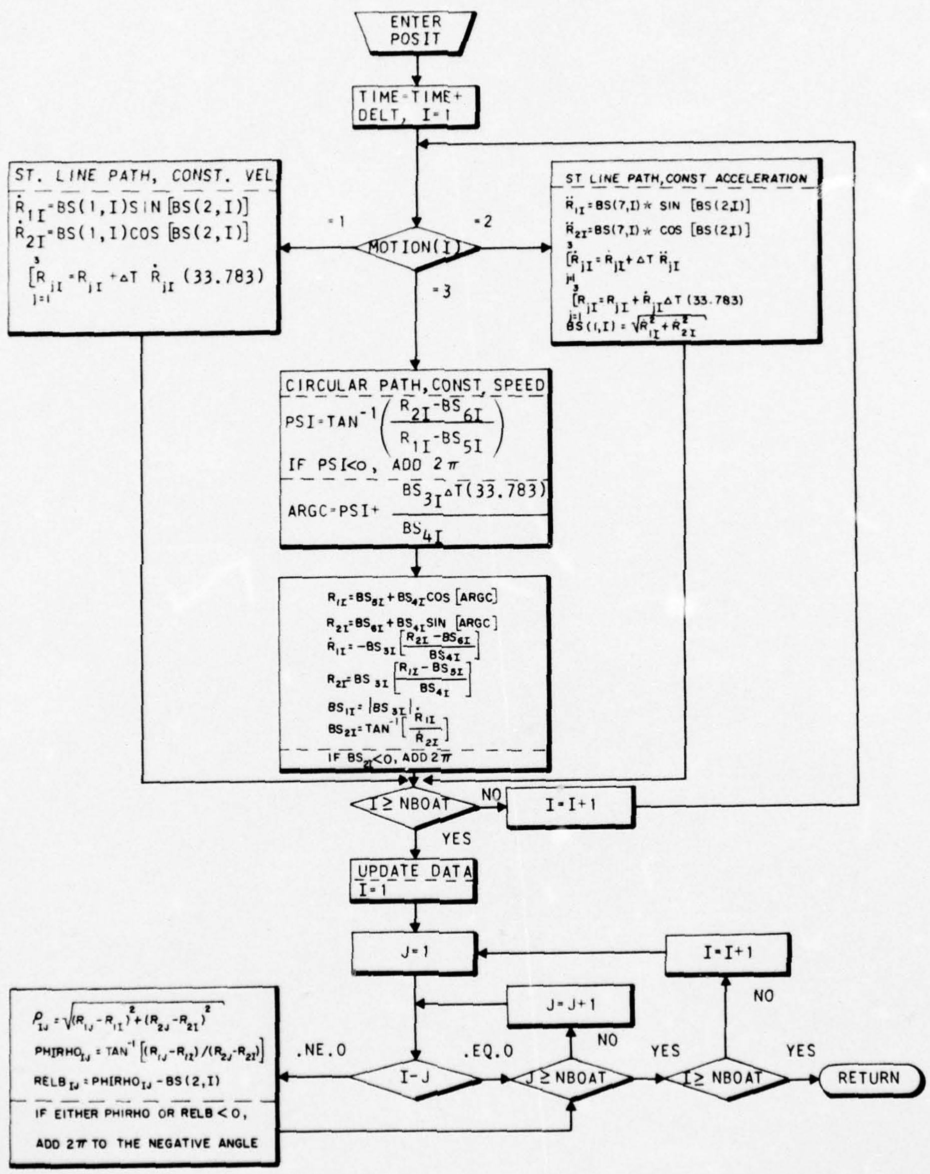

FIG. A-1 — POSIT FLOW CHART

TRACOR, INC DWG 86-62-301
AUSTIN, TEXAS 5-2-67 WEIDMAN

A.3 SUBSYS

PURPOSE: This subroutine evaluates the various subsystems for each of the boats in the simulation and stores the outputs in labeled common for reference by the TACTIC subroutine (i.e., for use by the boats to determine their future course of action).

INPUT:

TIME = Time (min)

NBOAT = Number of boats in the simulation

ISYSON = Array of flags indicating whether a subsystem on a particular boat is on (=1) or off (=0)

ITYPE = Array indicating the role of IBOAT in the simulation
- 0 = Barrier Boat
- 1 = Penetrator

NSS = Array containing total number of subsystems available to each boat according to the definitions of the first argument listed in control

IQUIP = Tag describing equipment available on a boat
- 0 = does not possess equipment
- 1 = does possess equipment

IDETEC = Flag denoting if boat has detected anyone
- 0 = no
- 1 = yes

DLSN = Threshold of useful information for the detection subsystem for IBOAT (dB)

RELB = Array of relative bearing of JBOAT from IBOAT, where IBOAT is the first index (radians)

BLIND = Array of blind spot angles for IBOAT (radians)

ISTART = Flag to instruct each boat whether or not to clear passive detection information field and rebuild (0 = rebuild). If non-zero, it indicates the index of the oldest S/N in the probability of detection table

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NPASSD	=	Array listing the number of points required to fill the S/N table used for passive detection
DETLM	=	Lower limit for probability of detection below which there is assumed to be no chance that detection can occur
LST	=	Length of time for which S/N is less than threshold before detection is assumed to be lost (min)
DELT	=	Length of each time step (min)
RHO	=	Actual distance between IBOAT and JBOAT (yds)
DI	=	Receiving directivity index for system NSYS (negative) (dB)
HEY	=	Array of random numbers used as keys for random number generator
PHIRHO	=	True bearing of JBOAT with respect to IBOAT (radians)
R	=	Vector of the true X, Y, and Z components of IBOAT in the Earth-fixed barrier coordinate system
ISYSRR	=	Number of subsystem providing range information to FIRCON and TRACK
ISYSTT	=	Number of subsystem providing bearing information to FIRCON and TRACK

OUTPUT:

STN	=	Array of signal-to-noise ratio's indexed by IBOAT, JBOAT and NSYS (dB)
PDF	=	Used to store array of S/N for each averaging process for each time step
PD	=	Array used to store maximum probability of detection for all averaging processes at each time step. The maximum value is stored in this array upon exit from the routine
SNAV	=	Array of the maximum average S/N computed at the current time step
NTIME	=	Number of points currently in the table of S/N ratios used to determine detection, up to the maximum allowable number

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NLOSS	=	Number of consecutive time steps for which detection has been lost
DR	=	Distance between IBOAT and JBOAT reported by ranging system NSYS (yds)
DRA	=	Actual error in DR (yds)
THET	=	Relative bearing of JBOAT from IBOAT reported by system NSYS (radians)
DTHET	=	Actual error in THET (radians)
TLOSS	=	Time since the classification subsystem was updated (min)
TCLASS	=	Length of time for which classification subsystem has been continuously gathering information (min)
ICLASS	=	Flag indicating that IBOAT has classified JBOAT with 0.90 probability
IPING	=	Flag indicating that JBOAT has detected IBOAT's ping
MFLGFR	=	Tracking flags indicating the status of the track for the fire control system
IFIR	=	Number of points in current fire control track
ITRK	=	Number of points in current track to determine target's base course
ALFFIR	=	Array of α-parameters determined in FIRCON (yds and kts)
SIGFIR	=	Array of standard deviations determined in FIRCON (yds)
XESTFR	=	Estimated current X-position of target in Earth-fixed barrier coordinate system from FIRCON (yds)
YESTFR	=	Estimated current Y-position of target in Earth-fixed barrier coordinate system from FIRCON (yds)
TLSTFR	=	Time track was last updated in FIRCON (min)
ALFTRK	=	Array of α-parameters determined in TRACK (yds and kts)
SIGTRK	=	Array of standard deviations determined in TRACK (yds)

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MFLGTK = Flags indicating whether or not TRACK has accurately determined the base course of the target

XESTTK = Estimated current X-position of target on base course in Earth-fixed barrier coordinate system (yds)

YESTTK = Estimated current Y-position of target on base course in Earth-fixed barrier coordinate system (yds)

TLSTTK = Time track was last updated in TRACK (min)

INTERNAL VARIABLES AND CONSTANTS:

IBOAT = Tag indicating the boat on which the subsystem is located

JBOAT = Tag indicating the boat about which information is being gathered

NSYS = Tag indicating the number of the subsystem under consideration

NSYSMX = Upper limit of do loop for each type of subsystem

IDDET1 = Number of time steps for which no useful information was accumulated prior to detection by Barrier Boat

IDDET2 = Serves same function for Penetrator that IDDET1 serves for Barrier Boat

INI = Least number of time steps before a probability of detection is computed

II = Number of S/N that will be averaged

SUM = Average S/N for the interval characterized by II

PDD = Probability of detection returned by PROBD

NRAN = Random number between 1 and 2000.

PDT = 1000 times the maximum probability of detection for the current time step

Increment by which DELTM is increased after each test for detection is 0.05

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SNT = Signal-to-noise ratio at JBOAT when IBOAT pings with an active sonar

IXFIR = Flat determining whether or not a fire control quality track has been achieved 1 = no
2 = yes

X = True bearing of JBOAT with respect to IBOAT reported by bearing subsystem, including error (radians)

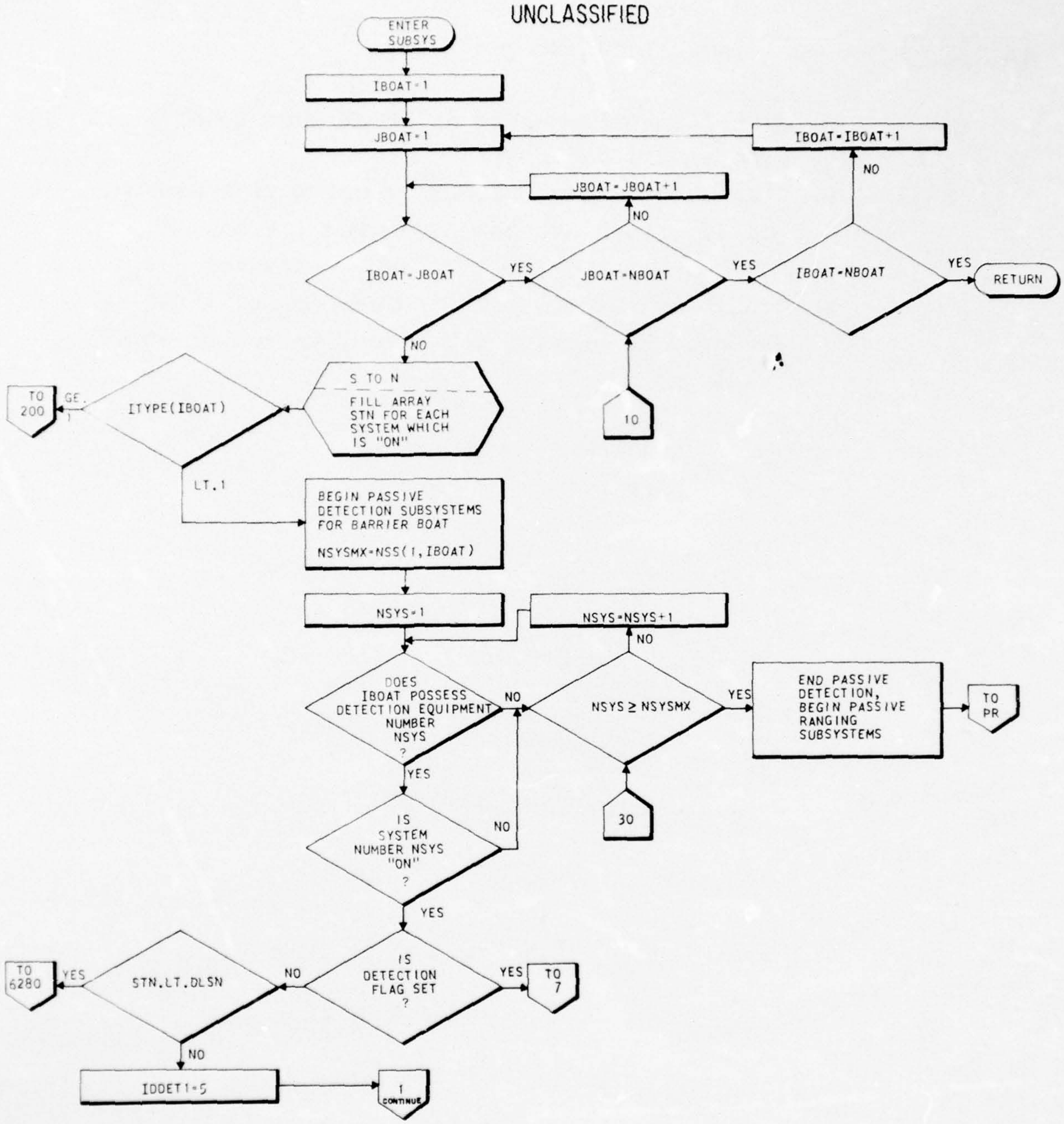

FIG. A-2 -SUBSYS FLOW CHART (PART I)

TRACOR, INC. DWG 06-62-297
AUSTIN, TEXAS 8-2-67 WEIDMAN

AD-A031 503 TRACOR INC AUSTIN TEX F/G 15/7
THE DEVELOPMENT OF A GENERAL COMBAT SIMULATION MODEL.(U)
SEP 67 J D STUART, F W WEIDMANN, S LAGRONE N00024-67-C-1572
UNCLASSIFIED TRACOR-67-751-U NL

3 OF 4
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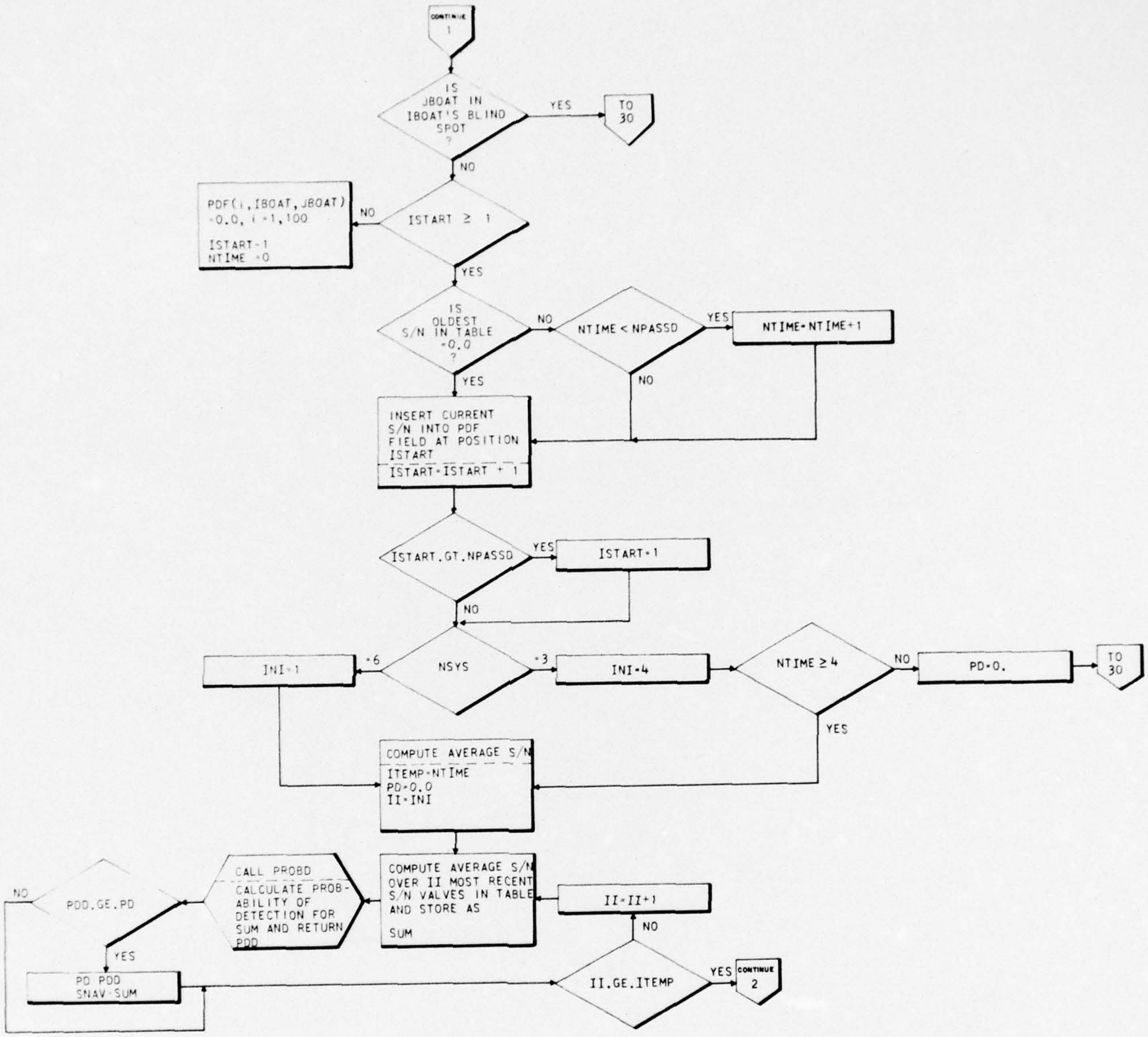

FIG. A-2 – SUBSYS FLOW CHART (PART 2)

TRACOR, INC DWG C6-62-261
AUSTIN, TEXAS 5-3-67 WEIDMAN

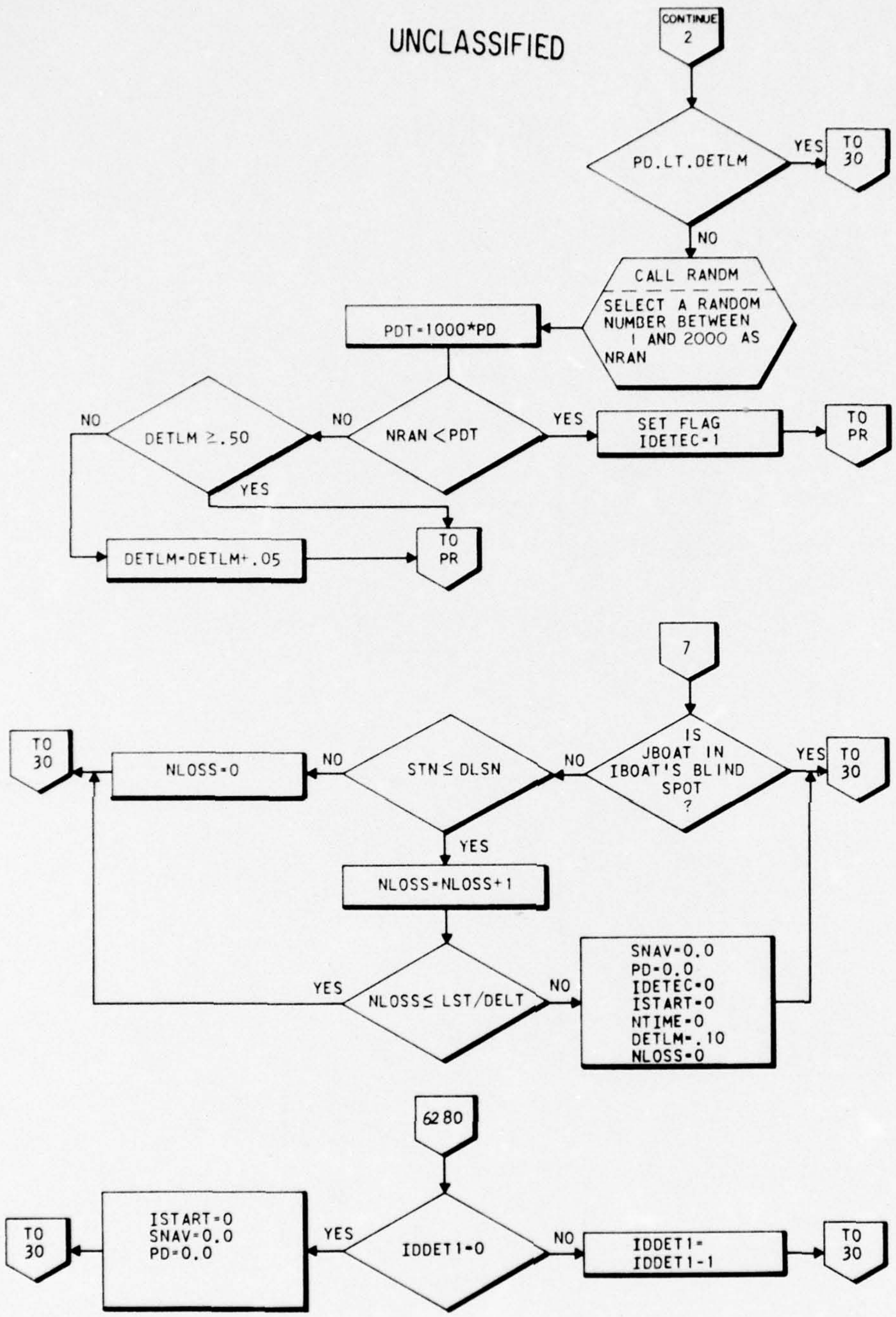

FIG. A-2 —SUBSYS FLOW CHART (PART 3)

TRACOR, INC DWG B6-62-288
AUSTIN, TEXAS 5-2-67 WEIDMAN

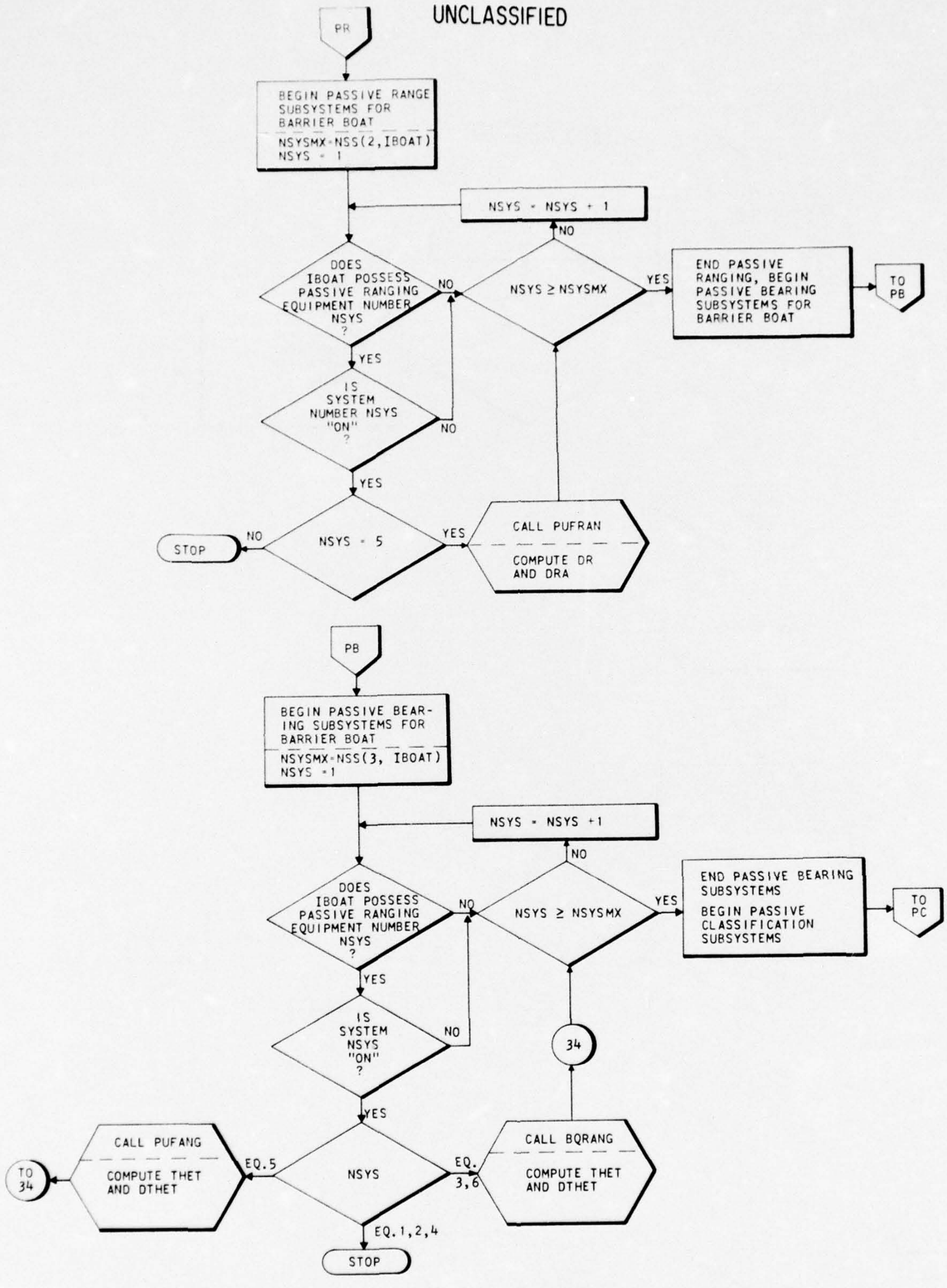

FIG. A-2 —SUBSYS FLOW CHART (PART 4)

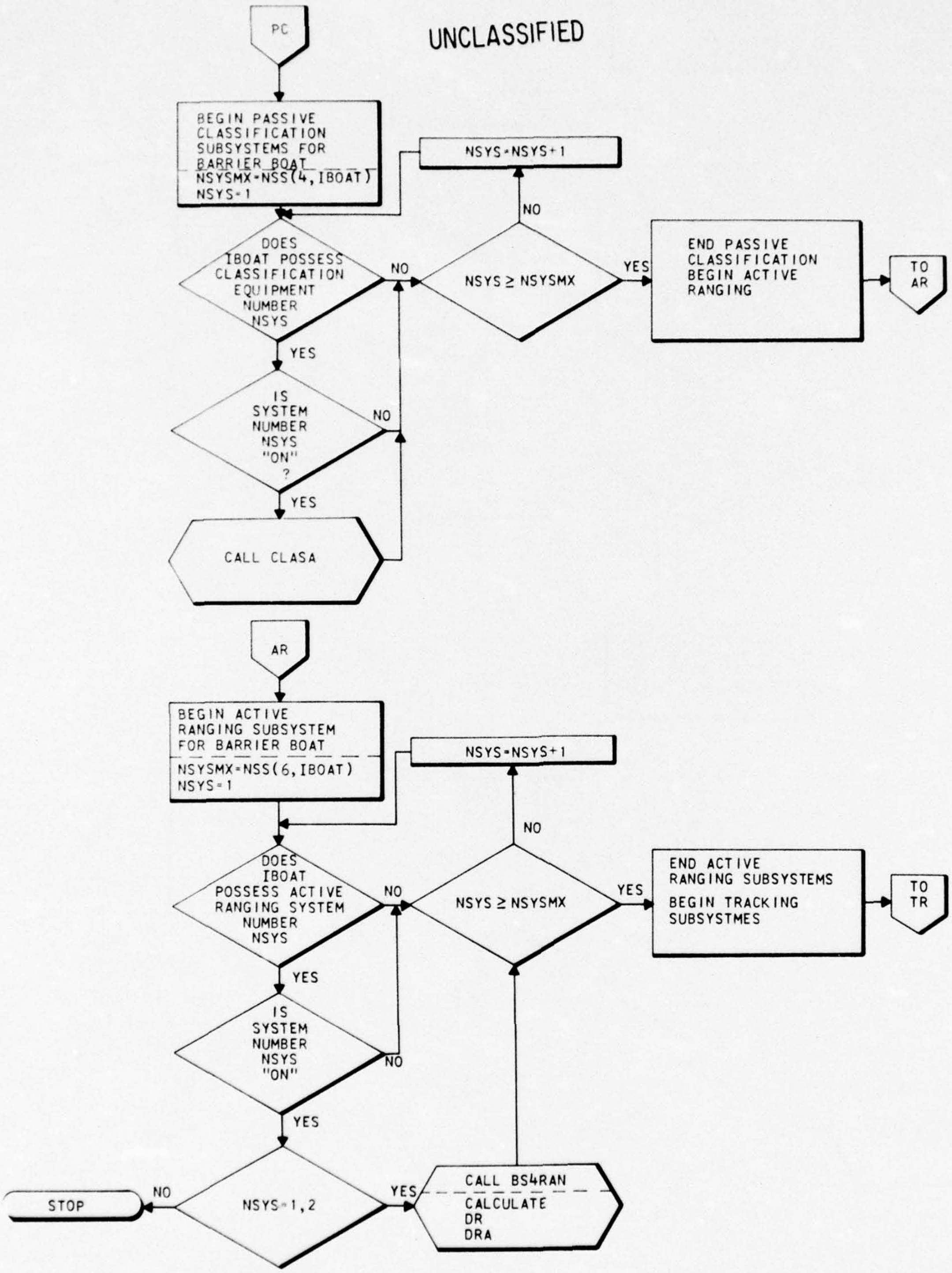

FIG. A-2 —SUBSYS FLOW CHART (PART 5)

TRACOR, INC DWG 86-62-290
AUSTIN, TEXAS 5-2-67 WEIDMAN

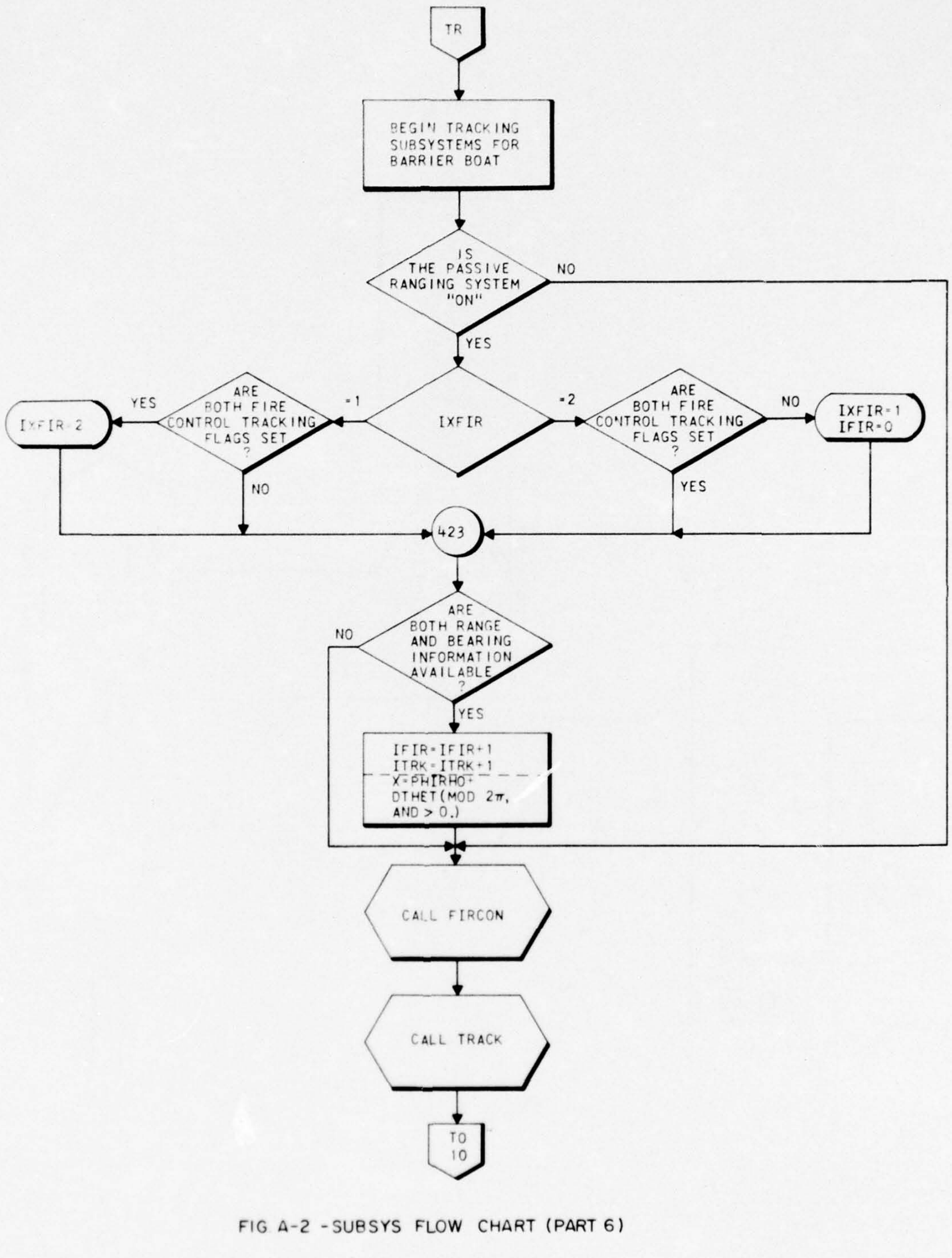

FIG A-2 -SUBSYS FLOW CHART (PART 6)

TRACOR, DWG B6-62-286
AUSTIN, TEXAS 4-28-67 WEIDMAN

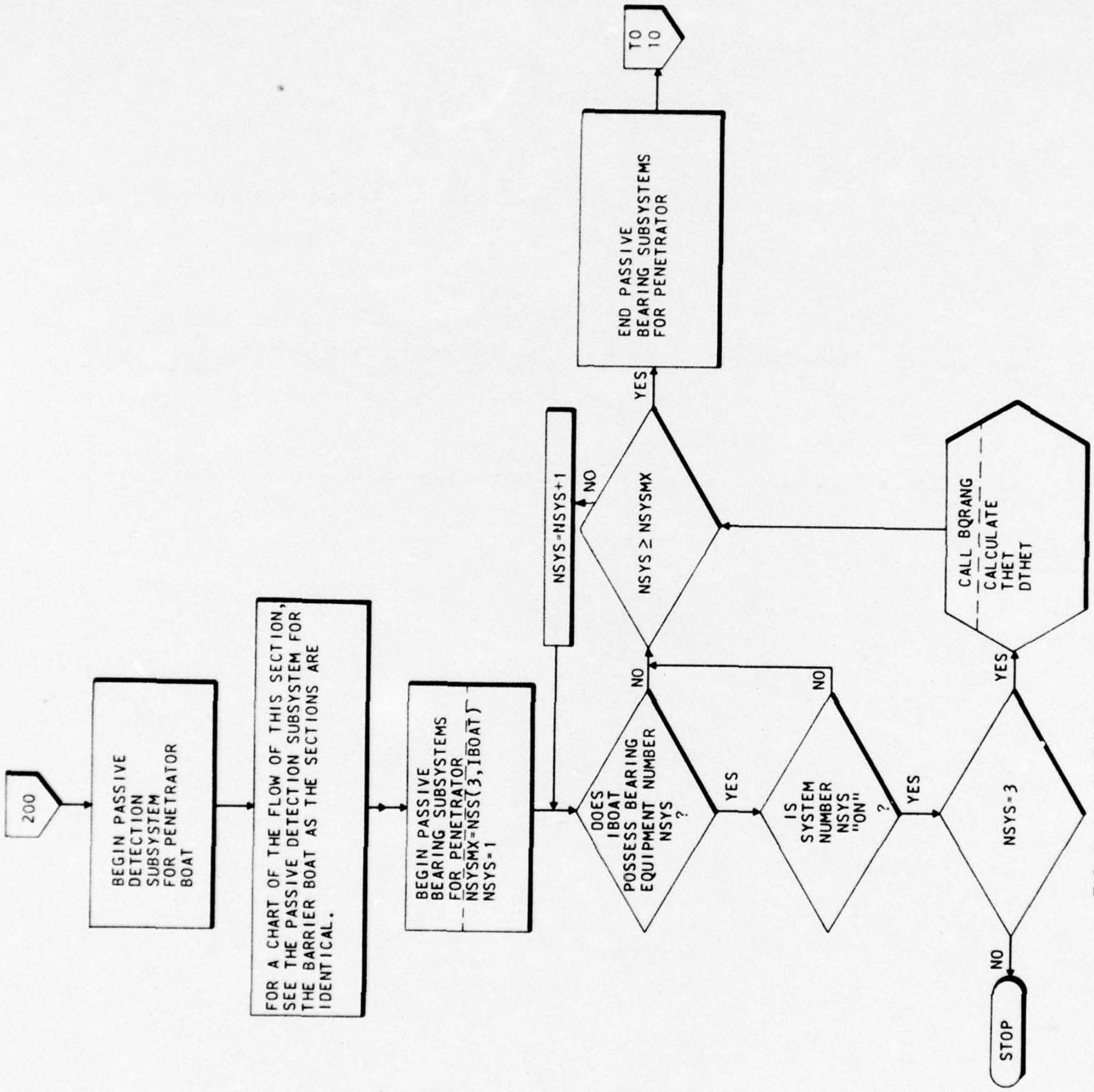

FIG. A-2 – SUBSYS FLOW CHART (PART 7)

TRACOR, INC DWG B6-62-292
AUSTIN, TEXAS 3-2-67 WEIDMAN

TRACOR 6500 TRACOR LANE, AUSTIN, TEXAS 78721

ATERPO

PURPOSE: The function ATERPO is a routine for straight line interpolation using the slope-Y-intercept form for a straight line.

INPUTS: There is one formal argument to the routine, ATERPO(B). B is the Y-intercept for the interpolation. All other inputs are in the form of a labeled common block called SNTAB2, the variables of which are X, S, T, D.

X is the X-value of the point to be interpolated

S and T are the two functional values used in the interpolation

D is the difference in abscissas of the two functional values

OUTPUT: The output is the interpolated value

FIG. A-3 — ATERPO FLOW CHART

TRACOR, INC. | DWG. A6-62-250
AUSTIN, TEXAS 4·21·67 WEIDMAN/SL

TRACOR 6500 TRACOR LANE, AUSTIN, TEXAS 78721

BQRANG

PURPOSE: This subroutine returns the relative bearing information determined by the AN/BQR-2B and the AN/BQR-2 (DIMUS). This is accomplished by taking the actual relative bearing between the two boats in question and adding to it a random error characteristic of the bearing errors of the 2B and 2 (DIMUS) equipment.

INPUT:

R	=	Actual range between the two boats (yds)
TIJ	=	Actual relative bearing between the two boats (radians)
SN	=	Signal-to-noise ratio at the output of the beamformer (dB)
HEY	=	A dimensioned array of random numbers
NSYS	=	A flag for determining whether the 2B or the 2 (DIMUS) is to be used to return information 3 = 2B 6 = 2 (DIMUS)

OUTPUT:

BIJ	=	Relative bearing returned by 2B or 2 (DIMUS) including error (radians)
DB	=	Bearing error characteristic of the 2B or 2 (DIMUS) (radians)

INTERNAL VARIABLES AND ARBITRARY CONSTANTS:

DR	=	Conversion factor from degrees to radians
RD	=	Recognition threshold below which equipment is inoperable (dB)

Blind area is a sector from 165^{o} to 195^{o} bearing in which the equipment can return no useful information.

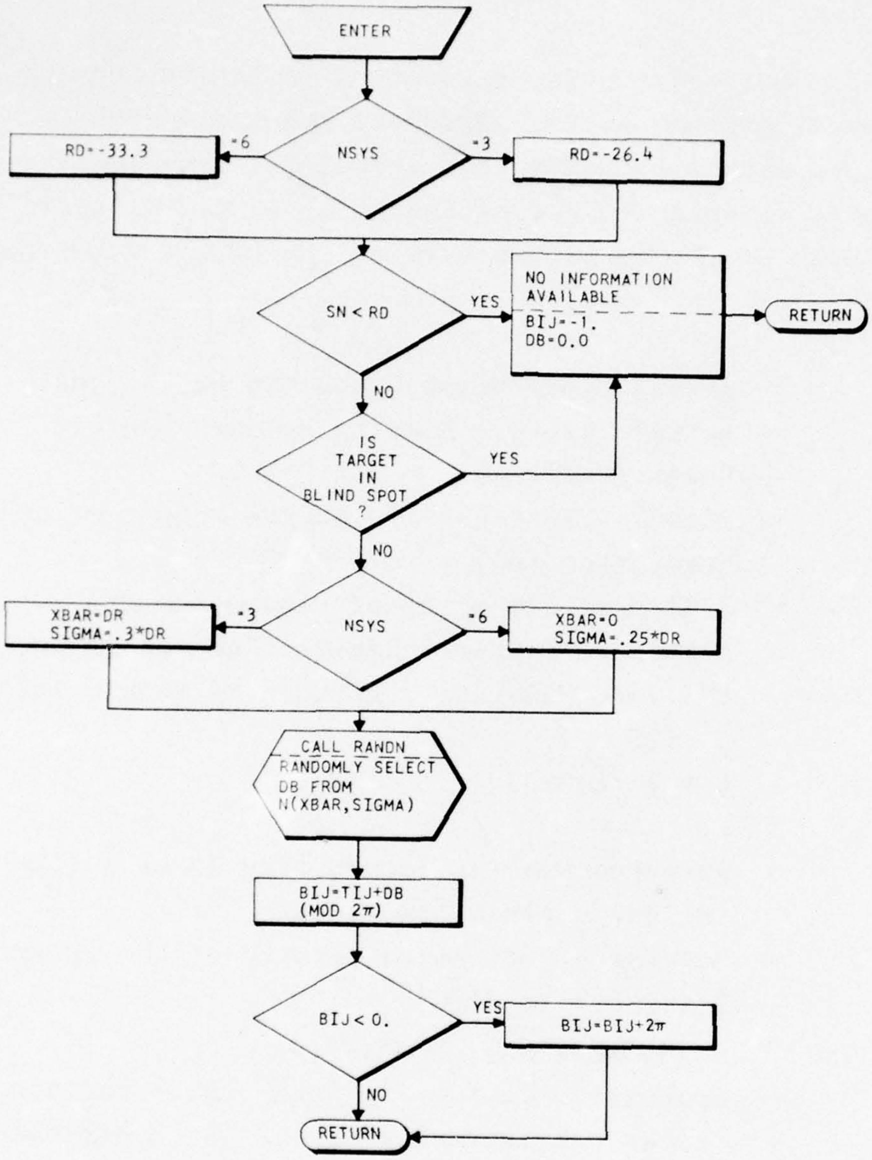

FIG. A-4 — BQRANG FLOW CHART

TRACOR, INC. DWG 86-62-283
AUSTIN, TEXAS 4-28-67 WEIDMAN

TRACOR 6500 TRACOR LANE, AUSTIN, TEXAS 78721

BS4RAN

PURPOSE: The purpose of this subroutine is to return the range determined by the BQS-4 and the BQS-4 (MOD 2). This is accomplished by adding to the actual range a random range error which is characteristic of the particular system being used.

INPUT:

R	=	Actual range between the two boats (yds)
TIJ	=	Actual relative bearing as seen by own ship (radians)
SN	=	Signal-to-noise ratio at own ship, measured at output of the beamformer (dB)
HEY	=	A dimensioned array of random numbers
TJI	=	Actual relative bearing as seen by target ship (radians)
IBOAT	=	Tag identifying own ship (ship gathering information)
JBOAT	=	Tag identifying target ship (ship which is object of information being gathered)
BLIND	=	A dimensioned array of the blind spot angular limits
IMOD	=	Tag indicating equipment to be modeled 1 = BQS-4 2 = BQS-4 (MOD 2)

OUTPUT:

IFLAG	=	Flag indicating whether JBOAT has been alerted by the ping of IBOAT (1 = alert, 0 = not alert)
SNT	=	Signal-to-noise ratio at JBOAT as a result of IBOAT's ping (dB)
RIJ	=	Range including error returned by the active system (yds)
DR	=	Range error characteristic of the active system used (yds)

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INTERNAL VARIABLES AND ARBITRARY CONSTANTS:

HALPD	=	Signal-to-noise level for which the active sonars have a 0.50 probability of detection (dB)
RD	=	Recognition threshold for JBOAT to detect IBOAT's ping (dB)
IMOD1	=	Tag used by subprogram STON to calculate the term SNT

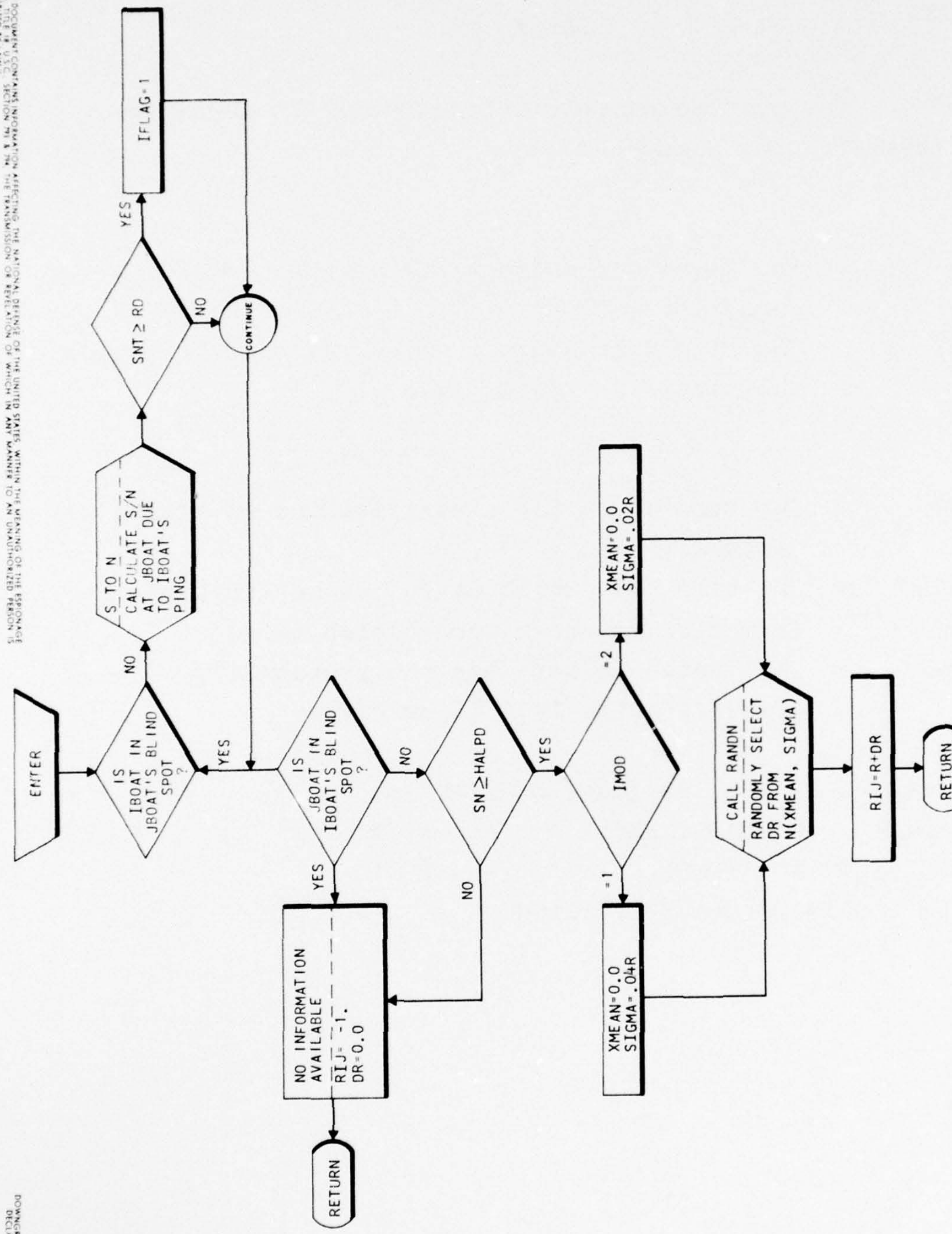

FIG. A-5 — BS4RAN FLOW CHART

TRACOR, INC DWG B6-62-285
AUSTIN, TEXAS 4-28-67 WEIDMAN

TRACOR 6500 TRACOR LANE. AUSTIN. TEXAS 78721

CLASA

PURPOSE: The purpose of this subroutine is to model the BQH-2C classification subsystem.

INPUT:

SN	=	The signal-to-noise ratio at the classification subsystem (dB)
DELT	=	The time increment at which the classification subsystem is updated (min)

OUTPUT:

TLOSS	=	The time since the classification subsystem was updated (min)
TCLASS	=	The time over which useful classification information has been accumulated (min)
ICLASS	=	Flag which is set when the probability of classification is 0.90 or higher

INTERNAL VARIABLES AND ARBITRARY CONSTANTS:

THRESHOLD FOR CLASSIFIER	=	-6 dB
UPPER LIMIT FOR TLOSS	=	1 min
LOWER LIMIT FOR CLASSIFICATION	=	20 min

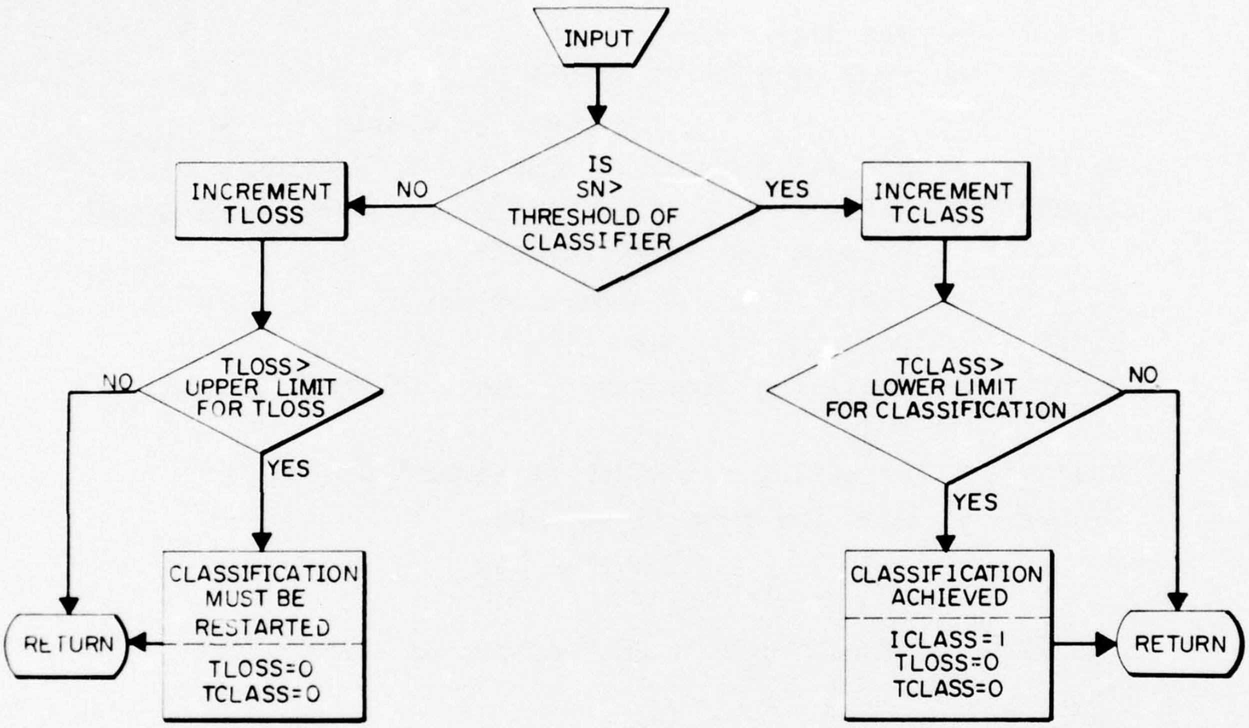

FIG. A-6 — CLASA FLOW CHART

TRACOR, INC. 1 DWG A6-62-249
AUSTIN, TEXAS 4-21-67 WEIDMAN/SL

TRACOR 6500 TRACOR LANE, AUSTIN, TEXAS 78721

FNOISE

PURPOSE: Function subprogram FNOISE determines the total masking, background noise seen by the receiving sonar.

INPUTS:

ISEAS	=	Sea State number
IKINDI	=	Type of boat 0 = Nuclear 1 = Diesel-Electric
FIISON	=	Operating frequency (center band) (Hz)
ATTENP	=	Absorption coefficient for propagation of sound through sea water (dB/yd)
RI	=	Depth of IBOAT (negative yds)
BSIBT	=	Velocity of IBOAT (kys)
DIISON	=	Receiving directivity index of sonar (negative) (dB)
DFIISN	=	Receiving bandwidth of sonar (Hz)
JSNORK	=	Flag for snorkel 0 = No 1 = Yes

OUTPUT:

The value of FNOISE is the only output of the routine

INTERNAL:

SEANOI and SEFNOI are called internally.

UNCLASSIFIED

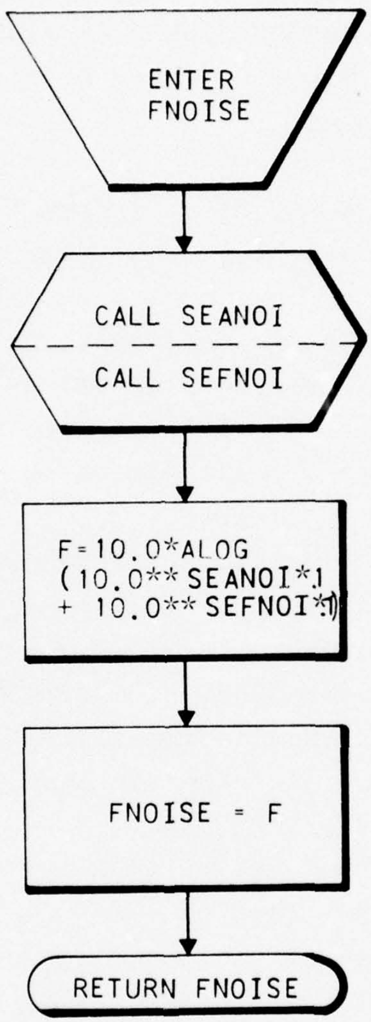

FIG. A-7 — FNOISE FLOW CHART

UNCLASSIFIED

TRACOR, INC. DWG. A6-62-269
AUSTIN, TEXAS 5-1-67 WEIDMAN

TRACOR 6500 TRACOR LANE, AUSTIN, TEXAS 78721

NOISY

PURPOSE: The subroutine NOISY is a three-dimensional interpolation /extrapolation routine to find a Y-value for a given X and Z. The Y-value is determined by interpolation in or extrapolation of a set of tabular values.

INPUTS: The inputs to NOISY are: 3 formal arguments, and a common block SNTAB1 with 7 variables. The formal arguments are:

1. Starting address of two-dimensional array of tabular values. The tabular values are Y-values.
2. Starting address of table of X-values which correspond to the first dimension of the Y-tabular values.
3. Size of first dimension of Y-tabular values, i.e., number of X-values.

The common block variables are:

1. X-value for interpolating/extrapolating
2. Z-value for interprolating/extrapolating
3. Index for start of values in X-array and first dimension of Y-arrays
4. Index for last of values in X-array and first dimension of Y-arrays
5. Array (dimensioned 4) of Z-values corresponding to 2nd dimension of Y-tabular values array. Z-values are step widths (or increments) between tables.
6. Number of Z-values for Z-array and 2nd dimension of Y-tabular values array
7. Variable for output.

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OUTPUTS: The only output from NOISY is that of the interpolated/extrapolated Y-value which is returned as the 7th variable in the common block SNTAB1.

INTERNAL: NOISY calls the function ATERPO to do all the interpolation/extrapolation. The inputs for ATERPO are: 1 formal argument, and a common block SNTAB2 with 4 variables.

The formal argument is the Y-intercept value for the straight line interpolation.

The common block variables are:

1. X-value to be interpolated for,
2&3. Two tabular values to interpolate or extrapolate from,
4. Difference between X-values of two tabular values.

UNCLASSIFIED

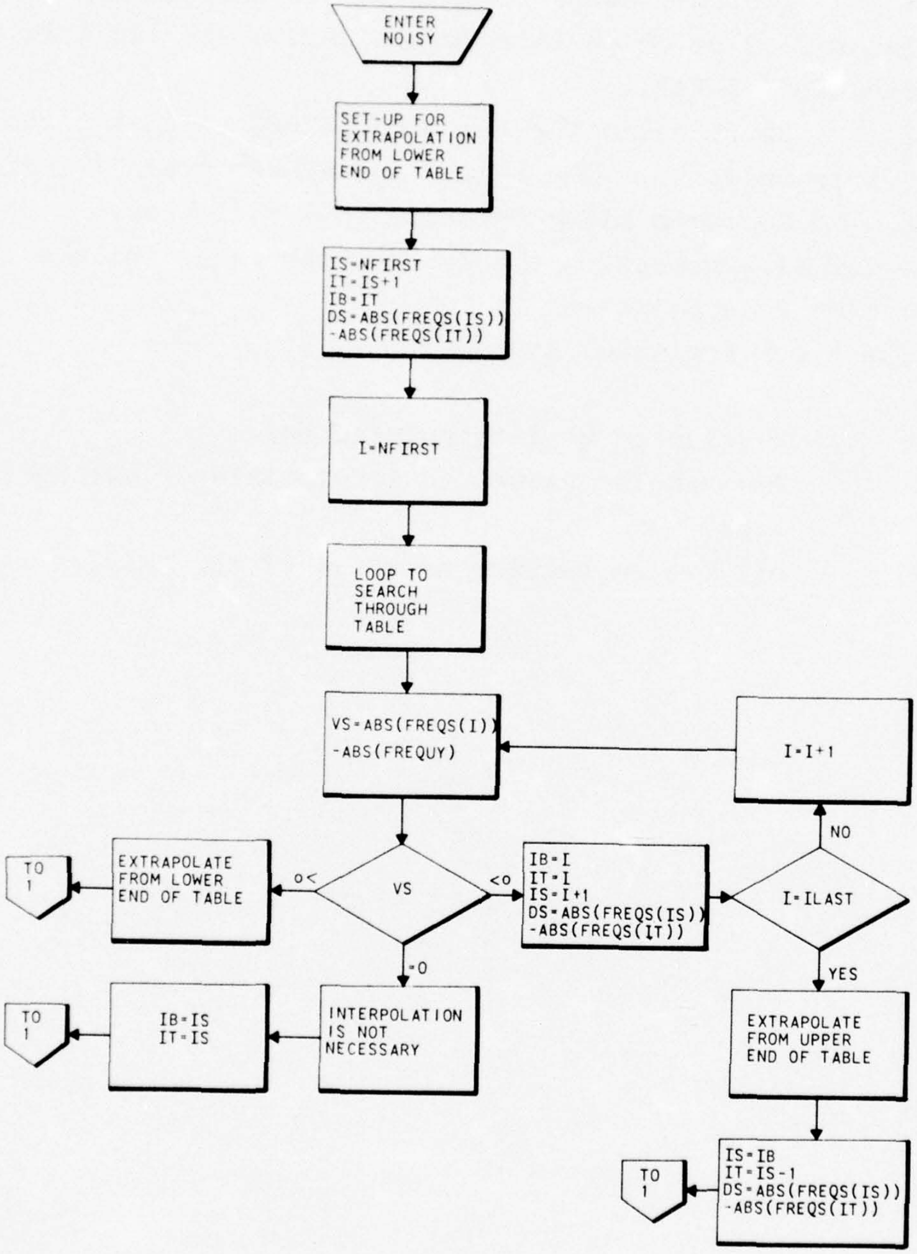

FIG. A-8 –NOISY FLOW CHART (PART I)

UNCLASSIFIED

TRACORINC DWG B6-62-282
AUSTIN, TEXAS 5-1-67 WEIDMAN

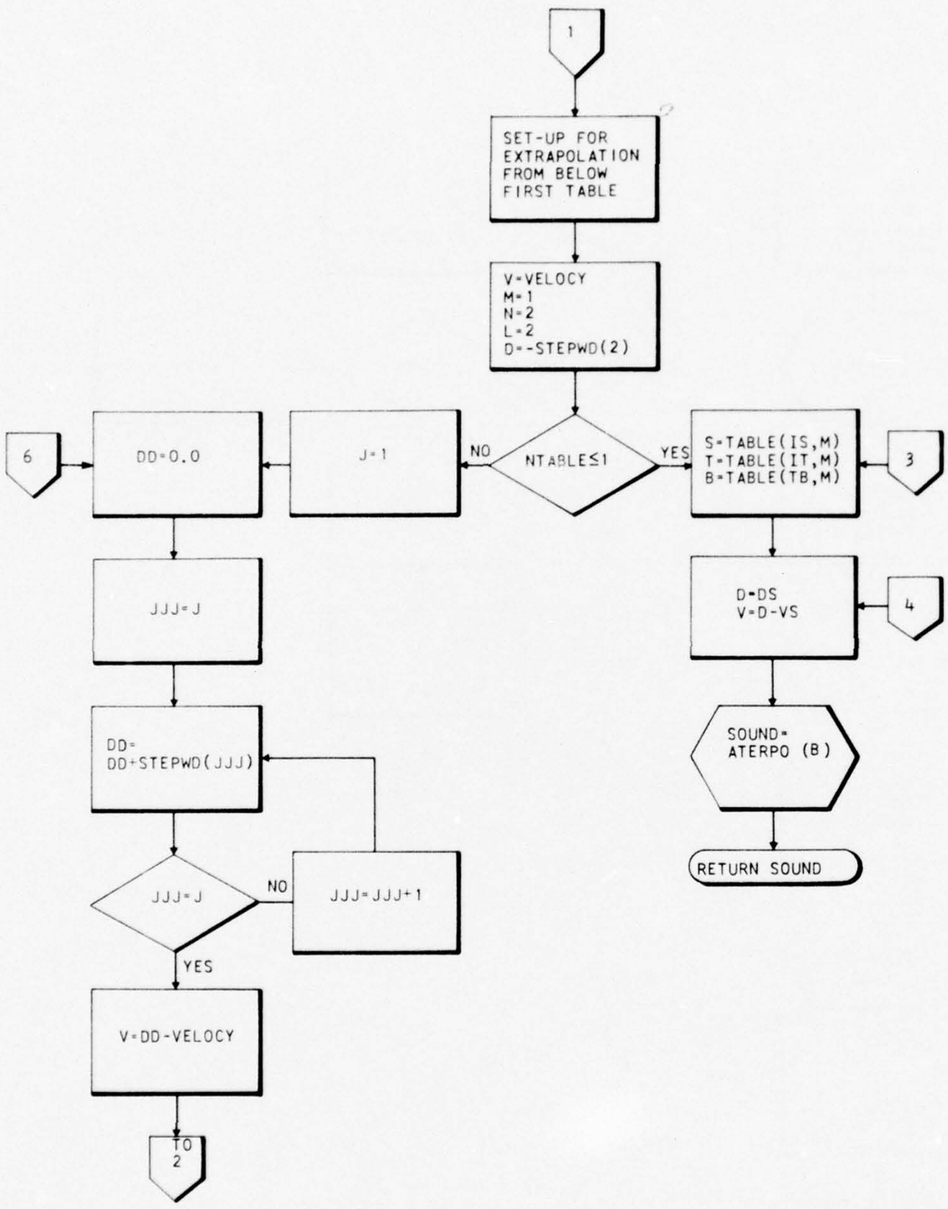

FIG. A-8 -NOISY FLOW CHART (PART 2)

TRACOR, INC DWG B6-62-296
AUSTIN, TEXAS 5-2-67 WEIDMAN

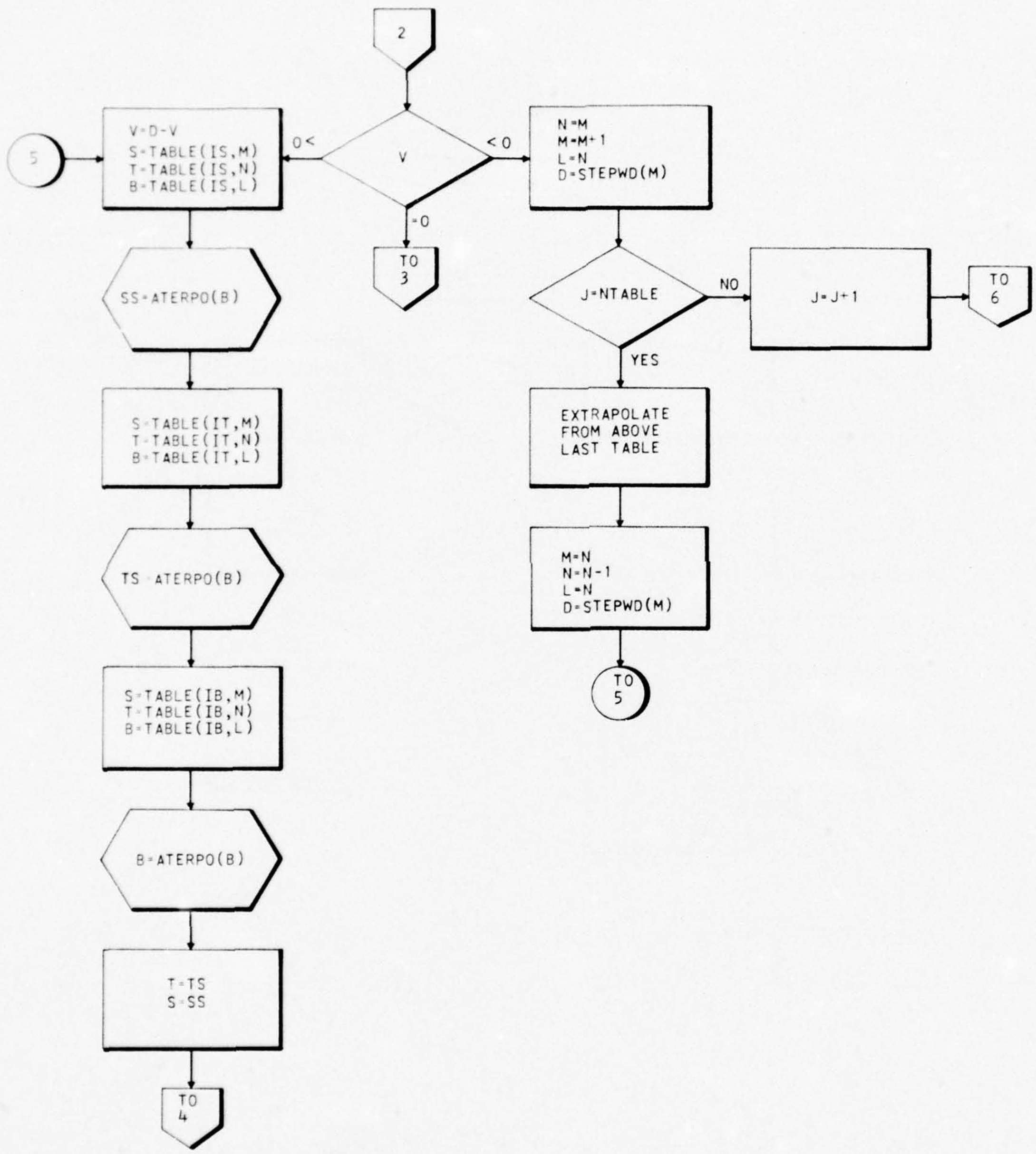

FIG. A-8 — NOISY FLOW CHART (PART 3)

TRACOR, INC DWGB6-62-291
AUSTIN, TEXAS 5-2-67 WEIDMAN

PRLOSS

PURPOSE: This function subprogram determines the propagation loss from a source to a receiver if the sonar mode is passive, and from the source to target to receiver if the sonar mode is active. This is accomplished by a table look-up technique, and the values stored in the tables are negative. The values stored in the tables are those for the path between the two boats which permits the highest intensity signal to reach the receiver.

INPUT:

ISONDX = Index indicating the type of sonar equipment
RI = Depth of IBOAT (negative) (yds)
RJ = Depth of JBOAT (negative) (yds)
RHOIJ = Range of JBOAT from IBOAT (yds)
INVERS = Flag for inverse interpolation 0 = No
1 = Yes

OUTPUT:

The value of PRLOSS is the only output of the routine

INTERNAL VARIABLES AND ARBITRARY CONSTANTS:

CDEPTH = Layer Depth = -33.3 (yds)

The variables of common block SNTAB1 must be set before calling NOISY.

FREQUY = Range in kyds
VELOCY = Not used = 0.0
NFIRST = Starting index in PROPAGATION LOSS TABLE
NLAST = Last index in PROPAGATION LOSS TABLE
STEPWD(1)= 0.0 (not used)
SOUND = Output from NOISY

For INVERSE INTERPOLATION, the input variable RHOIJ must be the propagation loss (multiplied by 1000.0), the call to NOISY has the X and Y arrays reversed.

NOISY has three formal arguments:

1. Starting address of X-array
2. Starting address of Y-array
3. Size of first dimension of X-array

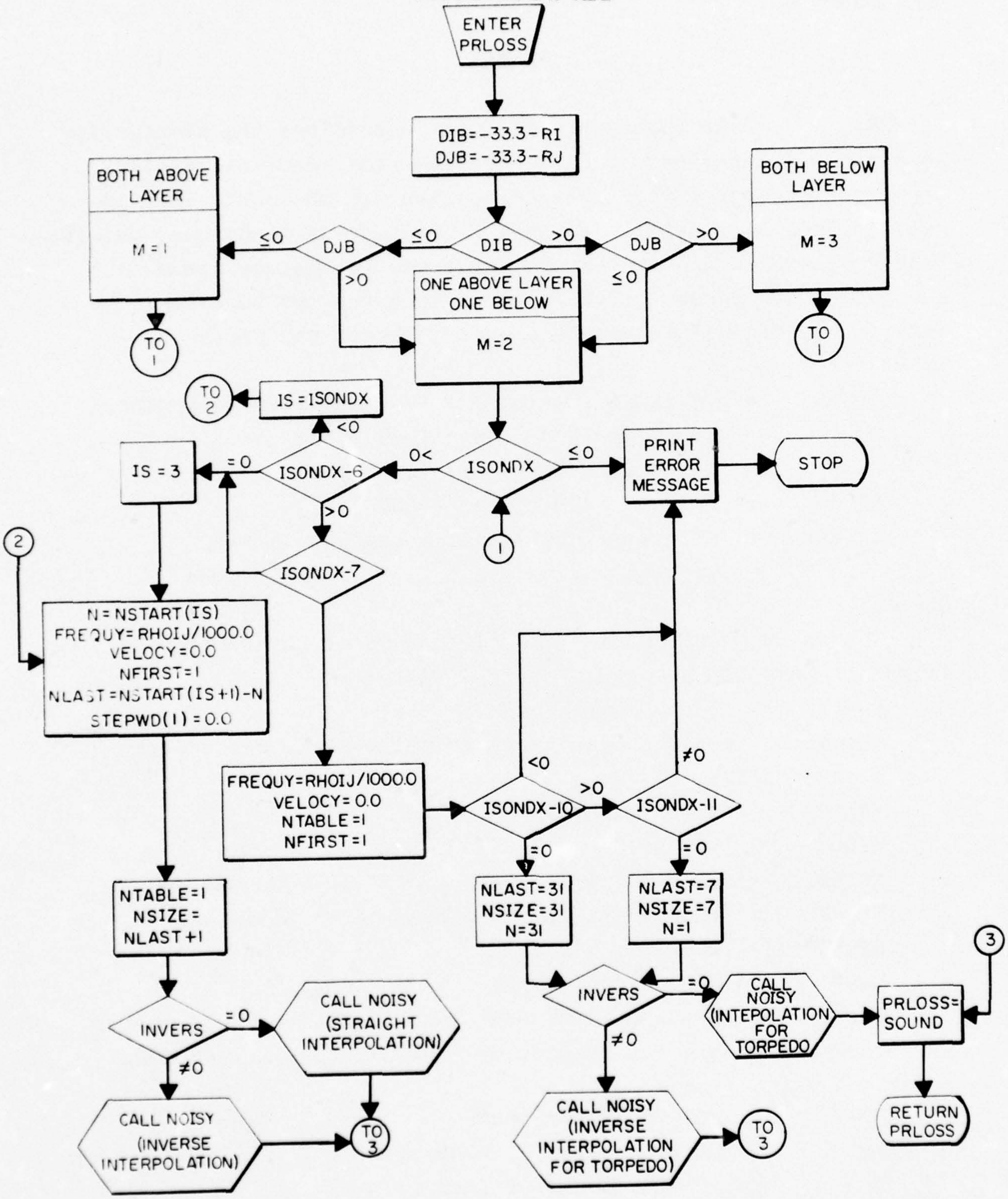

FIG. A-9 – PRLOSS FLOW CHART

TRACOR, INC. DWG A6-62-240
AUSTIN, TEXAS 4-17-67 WEIDMAN/SL

TRACOR 6500 TRACOR LANE, AUSTIN, TEXAS 78721

PROBD

PURPOSE: The subroutine PROBD is a routine to determine the probability of detection given a signal-to-noise ratio. If the maximum amount of usable detection data is not available then the signal-to-noise ratio is reduced. This reduction accounts for the fact that the tabular values are based on the maximum amount of detection data.

INPUT: There are 7 formal arguments to PROBD:

1.	ISONDX -	= 3 - Use tables for BQR-2B
		= 6 - Use tables for BQR-2 (DIMUS)
		= else - error halt
2.	DLSN	- not used
3.	DELT	- not used
4.	NTIME	- The time since the beginning of the simulation (min)
5.	SNAV	- Average S/N computed at the current time step (dB)
6.	NTMAX	- Maximum amount of usable detection data
7.	PDD	- Output

OUTPUT: The output is PDD - the probability of detection

INTERNAL: F(x) - A function for the reduction of S/N when the maximum amount of usable detection data is not available.

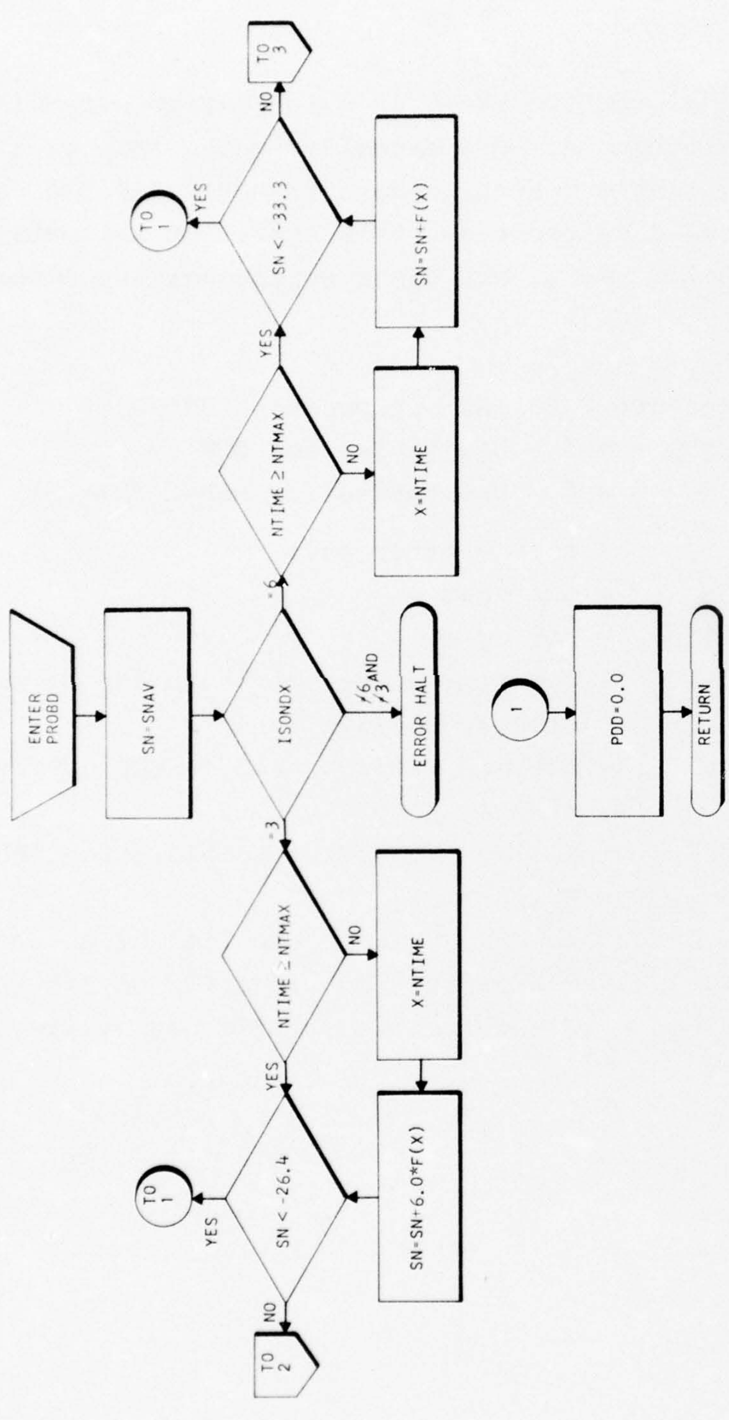

FIG. A-10 - PROBD FLOW CHART (PART I)

TRACOR, INC DWG B6-62-277
AUSTIN, TEXAS 5-2-67 WEIDMAN

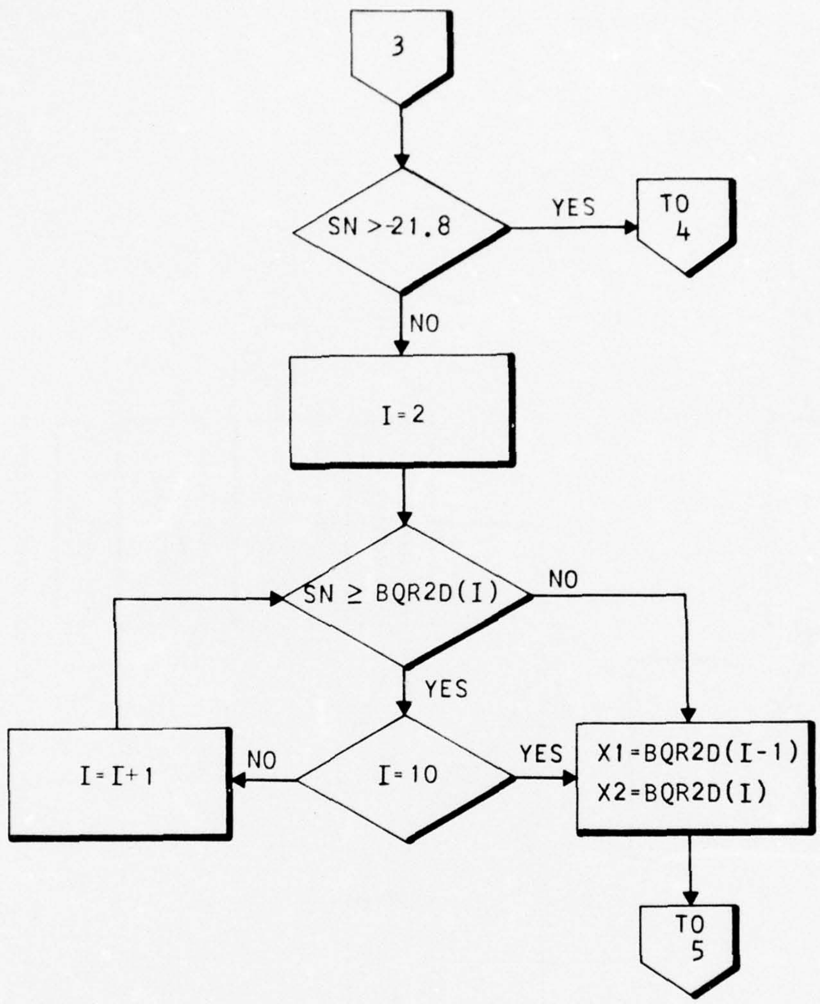

FIG. A-10 - PROBD FLOW CHART (PART 2)

TRACOR, INC. AUSTIN, TEXAS 5-1-67 DWG. A6-62-270 WEIDMAN

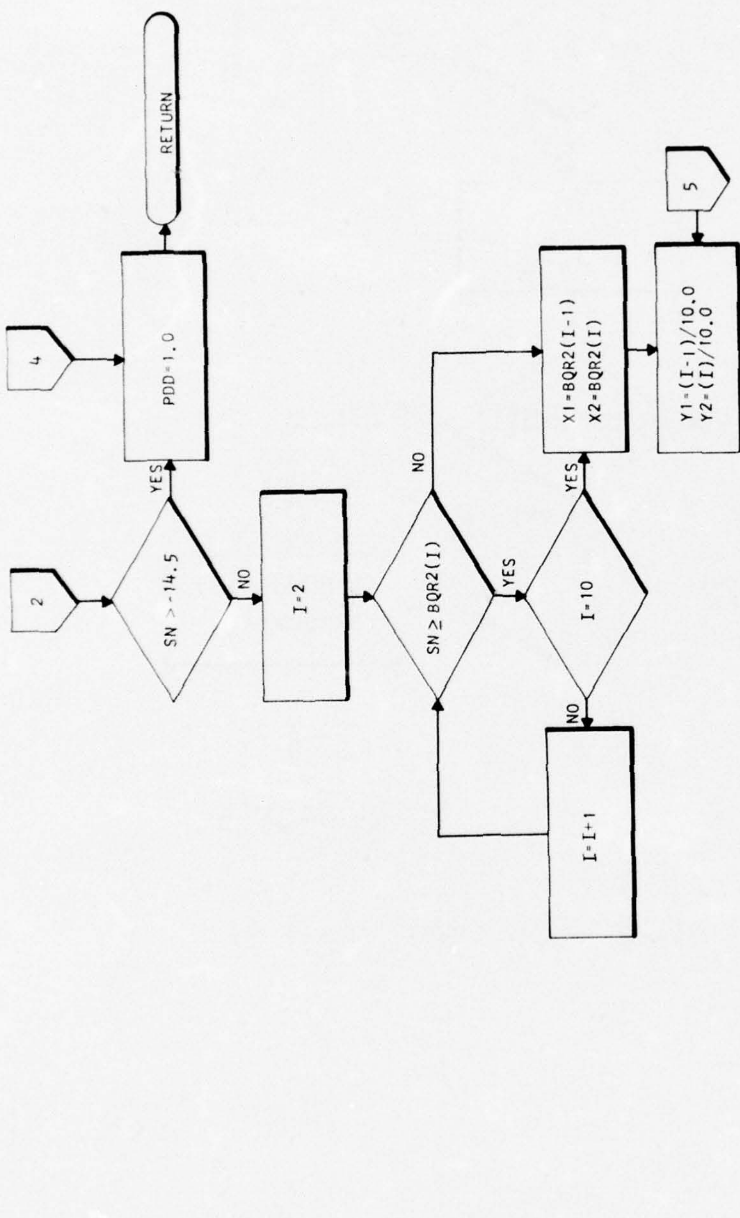

FIG. A-10 — PROBD FLOW CHART (PART 3)

TRACOR, INC DWG B6-62-278
AUSTIN, TEXAS 5-2-67 WEIDMAN

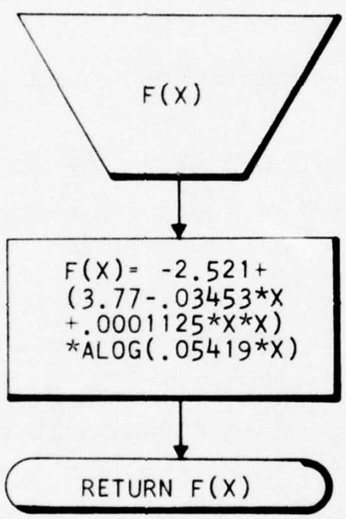

FIG. A-10 – PROBD FLOW CHART (PART 4)

TRACOR, INC. DWG. A6-62-274
AUSTIN, TEXAS 5-1-67 WEIDMAN

TRACOR 6500 TRACOR LANE, AUSTIN, TEXAS 78721

PUFANG

PURPOSE: This subroutine returns the relative bearing determined by the AN/BQG-4 (PUFFS). This is accomplished by taking the actual relative bearing between the two boats in question and adding to it a random error which is characteristic of the bearing error of the PUFFS equipment.

INPUT:

R = Range between the two boats (yds)

TIJ = Actual relative bearing between the two boats (radians)

SN = Signal-to-noise ratio at the output of the beamformer

HEY = A dimensioned array of random numbers

DI = Directivity Index of the PUFFS sonar (currently unused)

OUTPUT:

BIJ = Relative bearing returned by PUFFS including error (radians)

DB = Bearing error characteristic of the PUFFS equipment (radians)

INTERNAL VARIABLES AND ARBITRARY CONSTANTS:

RD = Recognition threshold below which PUFFS is inoperable (dB)

Maximum range beyond which PUFFS furnishes no useful information = 18000 yds. Angle sectors outside of which information from PUFFS is disregarded are $\pm$ 40^{o} of abeam.

T = Signal integration time for PUFFS correlator

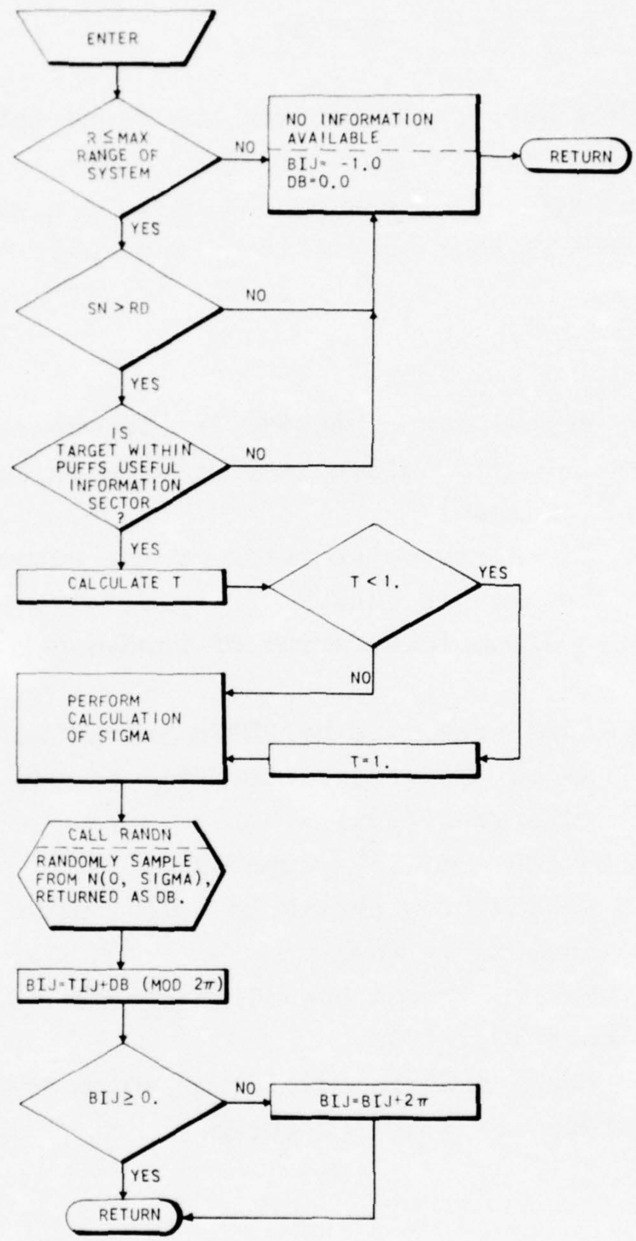

FIG. A-11 – PUFANG FLOW CHART

TRACOR, INC DWG B6-62-295
AUSTIN, TEXAS 5-2-67 WEIDMAN

TRACOR 6500 TRACOR LANE, AUSTIN, TEXAS 78721

PUFRAN

PURPOSE: This subroutine returns the range between the two boats determined by the AN/BQG-4 (PUFFS). This is accomplished by taking the actual range between the boats and adding to it a random error which is characteristic of the range error of the PUFFS equipment.

INPUT:

R	=	Actual range between the two boats (yds)
TIJ	=	Actual relative bearing between the two boats (radians)
SN	=	Signal-to-noise ratio at the output of the beamformer (dB)
HEY	=	A dimensioned array of random numbers

OUTPUT:

RIJ	=	Range returned by PUFFS including error (yds)
DR	=	Range error characteristic of the PUFFS equipment (yds)

INTERNAL VARIABLES AND ARBITRARY CONSTANTS:

RD	=	Recognition threshold below which PUFFS is inoperable (dB)

Maximum range beyond which PUFFS furnishes no useful information = 18000 yds.

Angle sectors outside of which information from PUFFS is disregarded are $\pm 40^{\circ}$ of abeam.

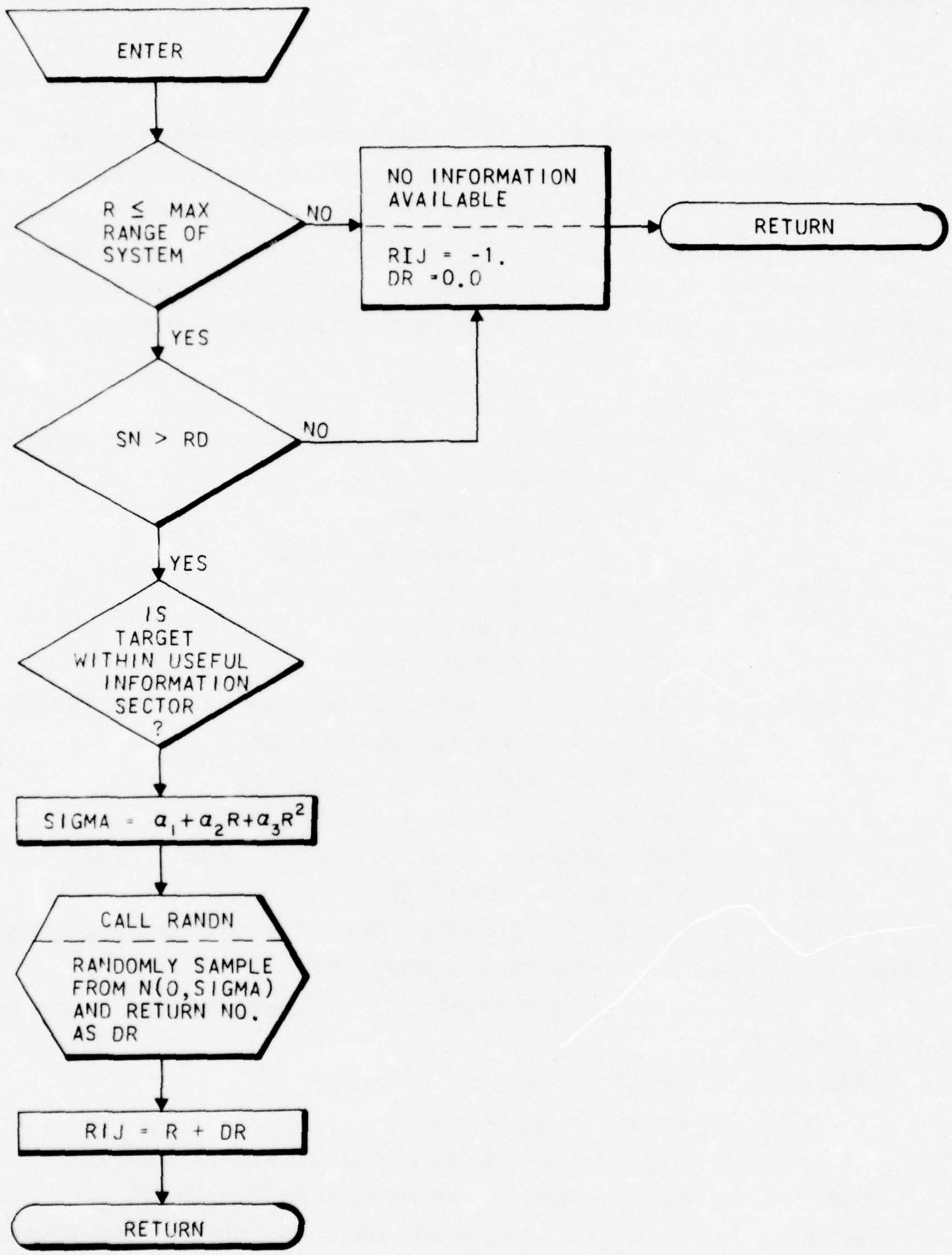

FIG. A-12 – PUFRAN FLOW CHART

TRACOR, INC. DWG. A6-62-276
AUSTIN, TEXAS 5-1-67 WEIDMAN

TRACOR 6500 TRACOR LANE, AUSTIN, TEXAS 78721

RADSIG

PURPOSE: The purpose of this function subprogram is to compute the passive signal received by IBOAT from JBOAT. This is accomplished by a table look-up of the spectrum level noise radiated at the center frequency of IBOAT's sonar, adjusting this value for the propagation loss between JBOAT and IBOAT and adding a term to account for the bandwidth of the receiver on IBOAT.

INPUT:

ISONDX = Index indicating the type of sonar equipment

IKINDJ = Type of boat
0 = Nuclear
1 = Diesel-Electric

JSNORK = Flag for snorkel
0 = No
1 = Yes

FIISON = Geometric or center frequency of sonar ISONDX (Hz)

RJ = Depth of JBOAT (negative)(yds)

RI = Depth of IBOAT (negative)(yds)

RHOIJ = Range of JBOAT from IBOAT (yds)

DFIISN = Receiving bandwidth of sonar JSONDX (Hz)

BSJBT = Velocity of JBOAT (kts)

OUTPUT: The value of RADSIG is the only output of the program

INTERNAL VARIABLES AND ARBITRARY CONSTANTS:

The variables in common block SNTABI must be set prior to calling NOISY.

FREQUY = Center frequency of sonar

VELOCY = Velocity of JBOAT

NFIRST = Starting index in radiated signal tables

NLAST = Last index in radiated signal tables

STEPWD = Array of stepwidths between tables, the first one being the velocity for the first table

TRACOR 6500 TRACOR LANE, AUSTIN, TEXAS 78721

NTABLE = Number of tables of radiated signals

SOUND = Output from subroutine NOISY

NOISY has three formal arguments:

1. Starting address of table of radiated signals
2. Starting address of center frequencies
3. Size of the first dimension on the array of signals

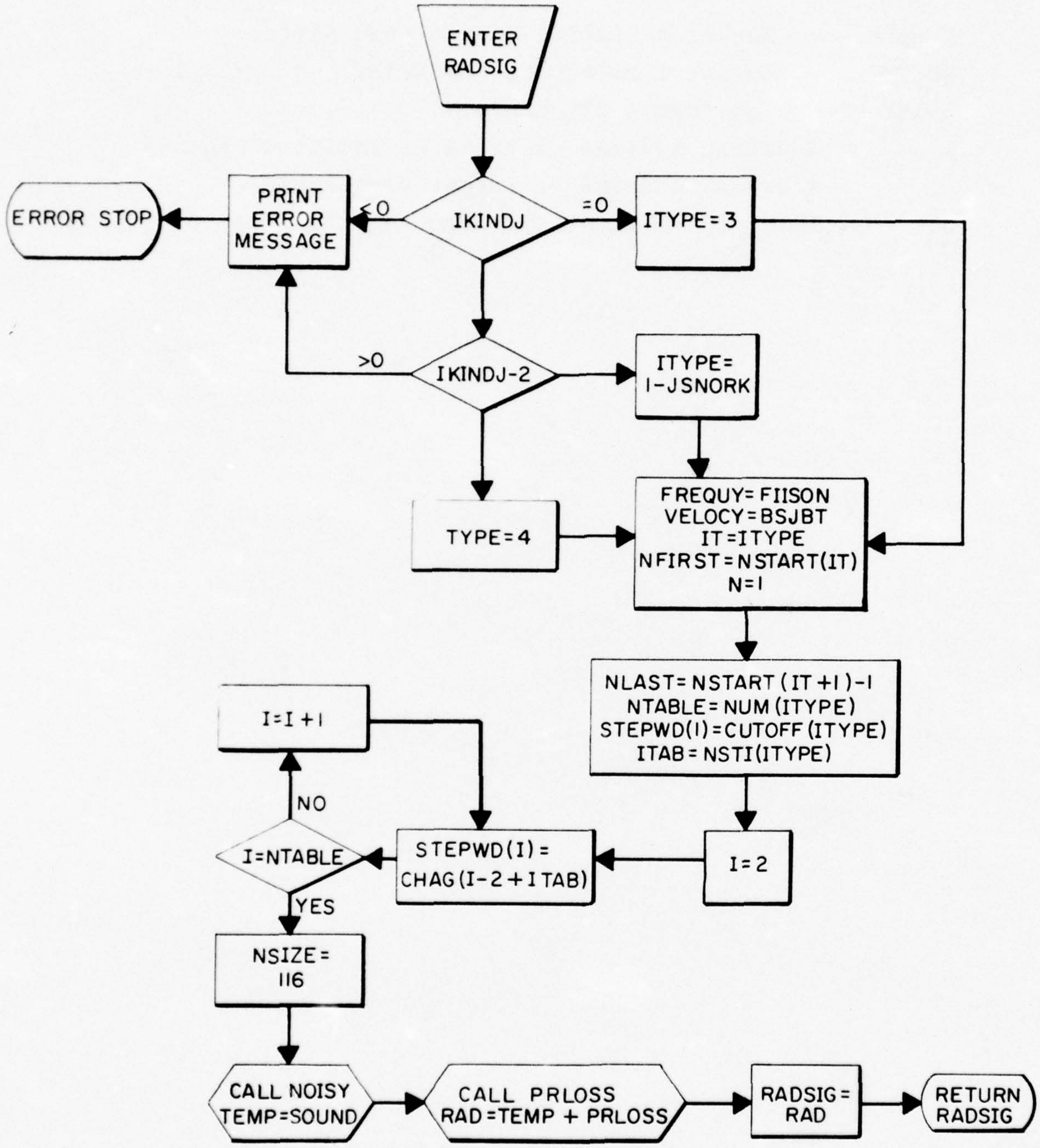

FIG. A-13 – RADSIG FLOW CHART

TRACOR, INC. DWG. A6-62-241
AUSTIN, TEXAS 4-17-67 WEIDMAN/SL

TRACOR 6500 TRACOR LANE, AUSTIN, TEXAS 78721

REFSIG

PURPOSE: This function subprogram determines the active signal received by IBOAT, after being adjusted for JBOAT's target strength and two-way propagation loss. The program also determines the signal received at JBOAT due to IBOAT's active ping, reduced by the one-way propagation loss.

INPUT:

ISONDX	=	Sonar index
RI	=	Depth of IBOAT (negative)(yds)
RJ	=	Depth of JBOAT (negative)(yds)
RHOIJ	=	Range of JBOAT from IBOAT (yds)

OUTPUT:

Value of REFSIG

INTERNAL VARIABLES AND ARBITRARY CONSTANTS

SOJ	=	Source level adjusted for the sending directivity index of the sonar

Target strength for the active sonar is assumed to be ±15 dB for all aspect angles.

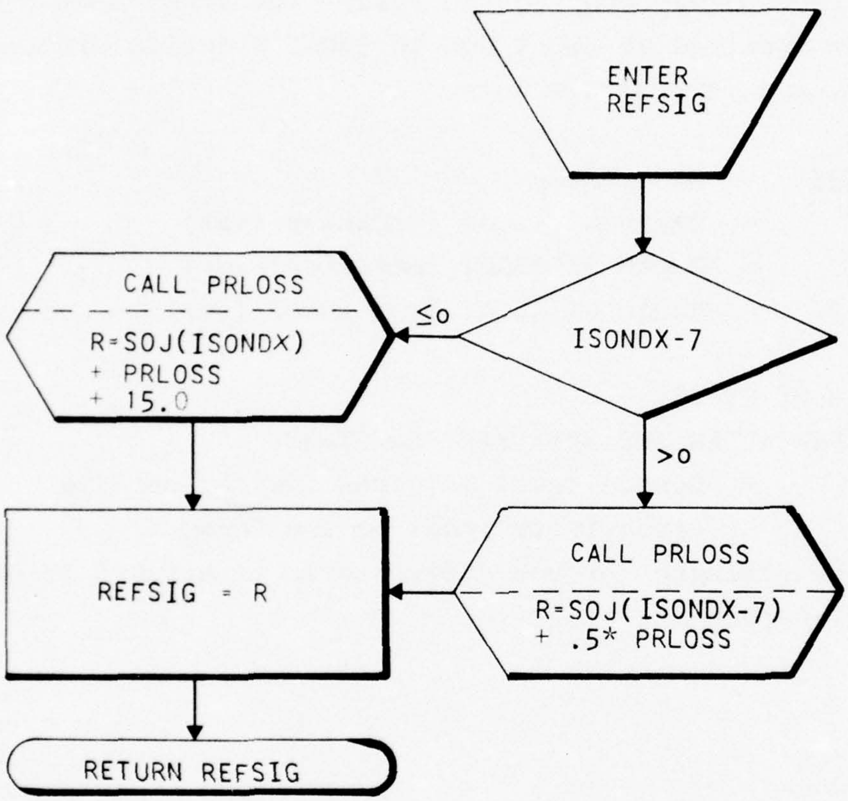

FIG. A-14 - REFSIG FLOW CHART

TRACOR, INC. AUSTIN, TEXAS 5-1-67 DWG A6-62-271 WEIDMAN

TRACOR 6500 TRACOR LANE, AUSTIN, TEXAS 78721

SEANOI

PURPOSE: Function SEANOI determines the background noise at the receiver due to Sea State. This is accomplished by taking Sea State and computing the Knudsen value for the spectrum level of the sound at the sonar frequency. This Knudsen value is adjusted for the depth of the receiver, the directivity index of the receiver, and the bandwidth of the receiver.

INPUT:

ISEAS	=	Sea State number
FIISON	=	Geometric or center frequency of sonar (Hz)
ATTENP	=	Absorption coefficient for the propagation of sound through sea water (dB/yd)
RI	=	Depth of IBOAT (negative)(yds)
DIISON	=	Receiving directivity index of sonar (negative) (dB)
DFIISN	=	Receiving bandwidth of sonar (Hz)

OUTPUT:

The value of SEANOI is the only output of the routine

INTERNAL VARIABLES AND ARBITRARY CONSTANTS:

B(ISEAS+1) - Array of Y-intercepts for Knudsen curves

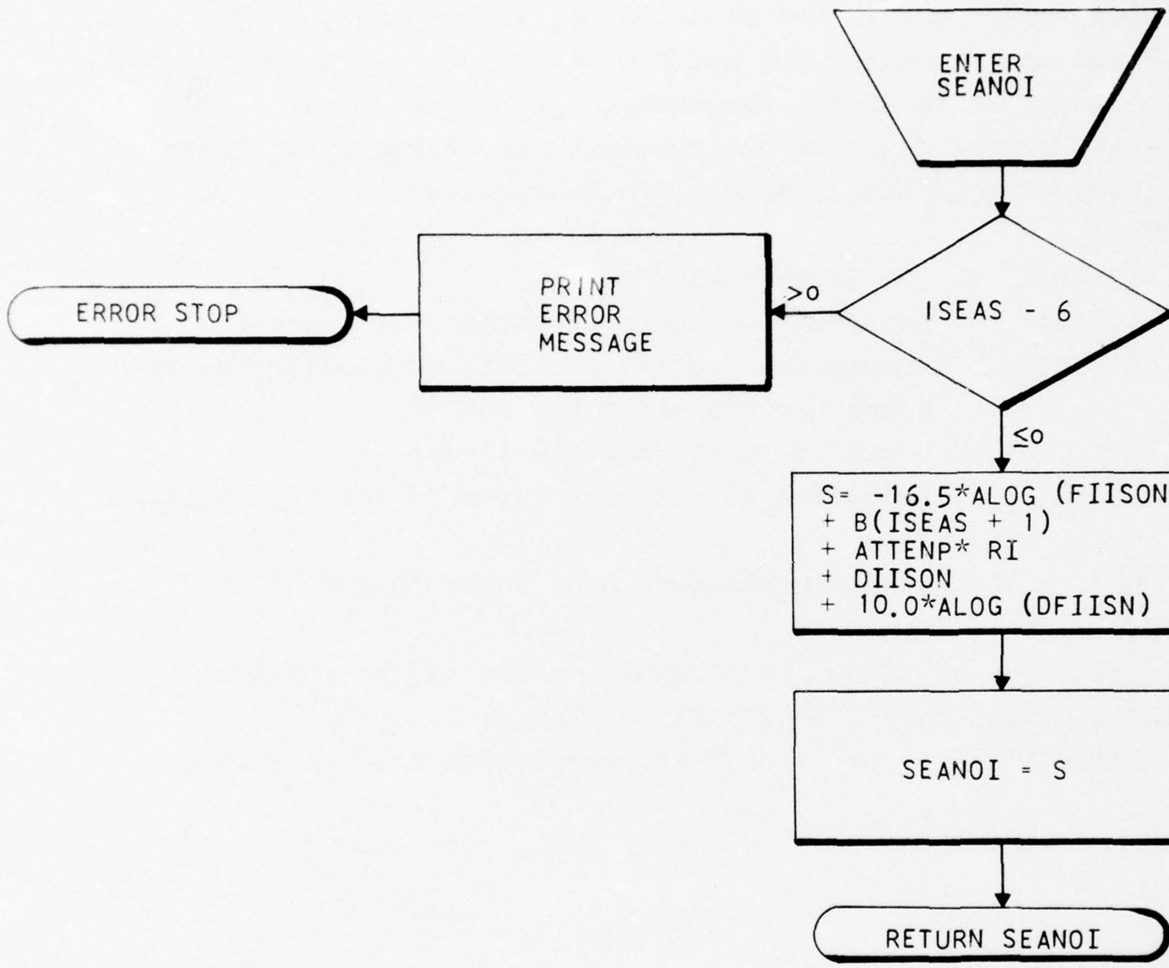

FIG. A-15 —SEANOI FLOW CHART

TRACOR, INC. DWG. A6-62-272
AUSTIN, TEXAS 5-1-67 WEIDMAN

TRACOR 6500 TRACOR LANE, AUSTIN, TEXAS 78721

SEFNOI

PURPOSE: This function subprogram computes the self-noise seen by the sonar receiver on IBOAT. This self-noise is stored in a table, and the tabular value is adjusted for the receiving directivity index and bandwidth of the receiver.

INPUT:

IKINDI	=	Type of Boat	0 = Nuclear 1 = Diesel-Electric
FIISON	=	Geometric or center frequency of sonar (Hz)	
BSIBT	=	Velocity of IBOAT	
DIISON	=	Receiving directivity index of sonar (negative) (dB)	
DFIISN	=	Receiving bandwidth of sonar (Hz)	
JSNORK	=	Flag for snorkel	0 = No 1 = Yes

OUTPUT:

The value of SEFNOI is the only output of the routine

INTERNAL:

Before calling NOISY (TABLE INTERPOLATION ROUTINE), the variables of common block SNTAB1 must be set.

FREQUY	=	FIISON
VELOCY	=	BSIBT
NFIRST	=	Index of start in noise array
NLAST	=	Index of last in noise array
STEPWD	=	1st in array is velocity for first table, rest are stepwidths in velocity between tables
NTABLE	=	Number of tables = Z
SOUND	=	Output from NOISY

NOISY also has three formal arguments:

1. Array of self-noise values
2. Array of operation frequencies
3. Size of IST dimension of self-noise values

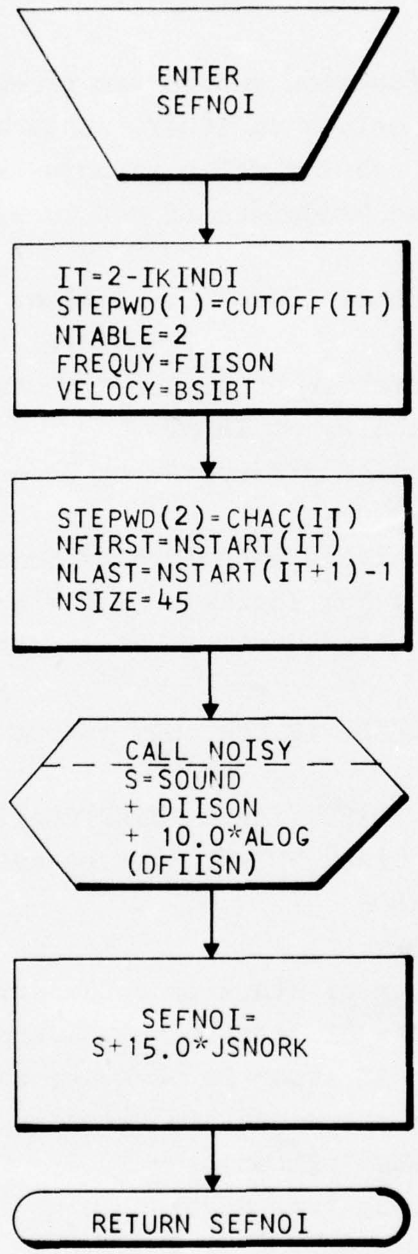

FIG. A-16 — SEFNOI FLOW CHART

TRACOR, INC. DWG. A6-62-273
AUSTIN, TEXAS 5-1-67 WEIDMAN

TRACOR 6500 TRACOR LANE, AUSTIN, TEXAS 78721

STON

PURPOSE: The purpose of this function subprogram is the return the signal-to-noise ratio received at IBOAT from JBOAT, when IBOAT is using the sonar equipment indexed ISONDX.

INPUT:

IBOAT	=	Index of boat on which the sonar equipment is located (own boat)
JBOAT	=	Index of boat which is the target
ISONDX	=	Index indicating the type of sonar equipment for IBOAT
ISEAS	=	Sea State number
ATTENP	=	Array of absorption coefficient for the propagation of sound through sea water (dB/yd)
F	=	Geometric or center frequency of sonar ISONDX (Hz)
DF	=	Received bandwidth of sonar ISONDX (Hz)
DI	=	Receiving directivity index of sonar ISONDX (negative)(dB)
ISNORK	=	Flag for snorkel 0 = No 1 = Yes
R(3,JBOAT)	=	Depth of JBOAT (negative)(yds)
R(3,IBOAT)	=	Depth of IBOAT (negative)(yds)
BS(1,IBOAT)	=	Velocity of IBOAT (kts)
RHO	=	Actual range between IBOAT and JBOAT
IKIND	=	Type of boat 0 = Nuclear 1 = Diesel-Electric

OUTPUT: The value of STON is the only output of the program

INTERNAL VARIABLES AND CONSTANTS:

The value +8 dB has been added to the S/N ratio calculated from the tables to correspond with the <u>SS/SSN Preliminary Cost Effectiveness Analysis</u> noise curves.

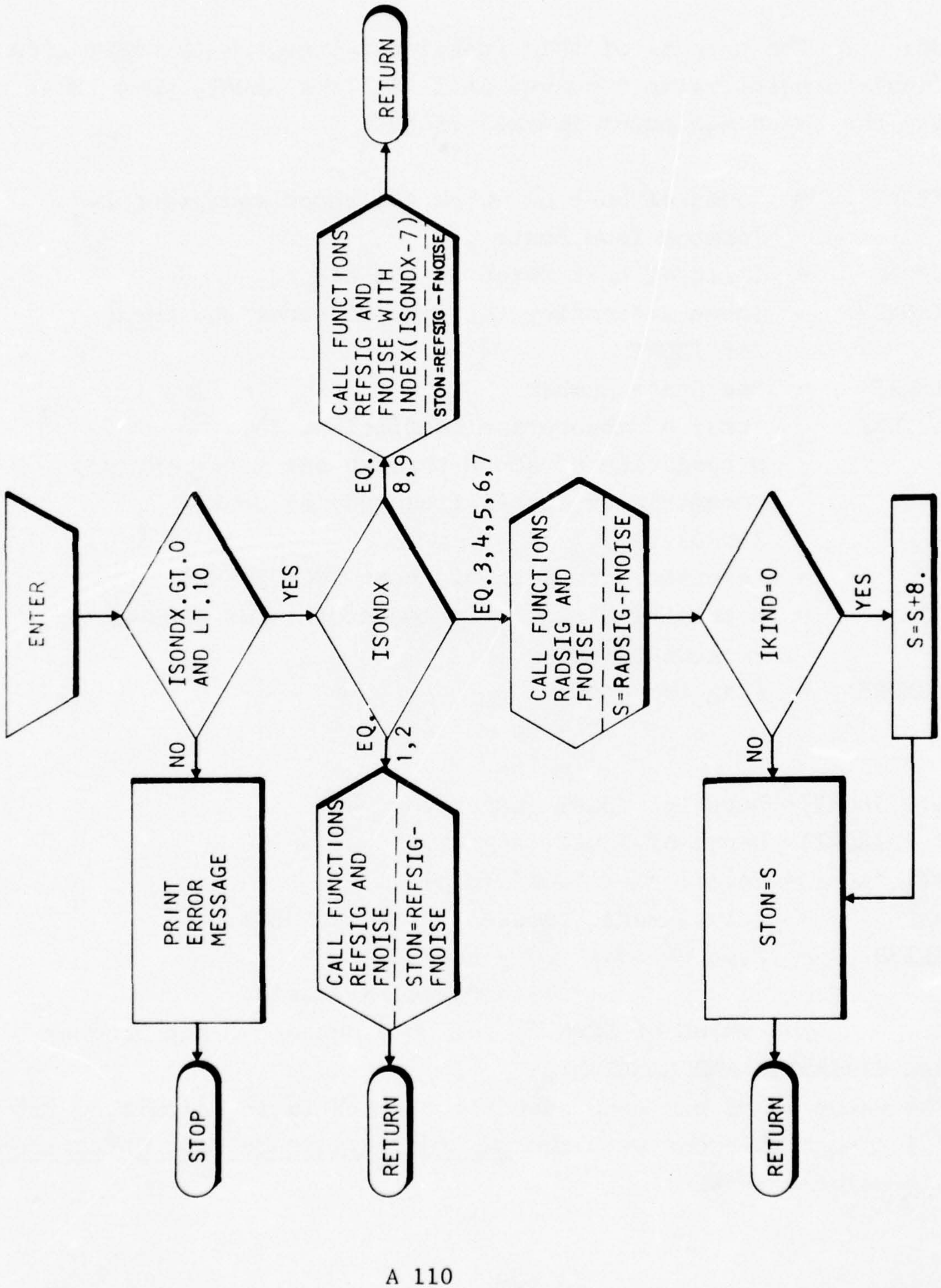

FIG. A-17 —STON FLOW CHART

TRACOR, INC DWG A6-62-289
AUSTIN, TEXAS 5-2-67 WEIDMAN

TRACOR 6500 TRACOR LANE, AUSTIN, TEXAS 78721

A.4 TACTIC

PURPOSE: This subroutine evaluates the information provided by the subsystems of each boat, and makes tactical decisions based on the tactical doctrine under which the boat is operating.

As the simulation currently involves only two boats, the boat making the decisions is termed IBOAT and the other boat is termed JBOAT for purposes of describing the variables used in the program.

Certain variables are generated in TACTIC at one time step for use by TACTIC at a later time step. As such, these variables are both input and output variables of tactics. In addition, there are certain variables which are either pure input or pure output. For this routine, all variables are lumped into one general category.

VARIABLES USED IN TACTIC:

TIME	= Current time (min)
XMAX	= Maximum X-coordinate value for barrier (yds)
YMAX	= Maximum Y-coordinate value for barrier (yds)
ZMAX	= Maximum Z-coordinate value for barrier (yds)
XMIN	= Minimum X-coordinate value for barrier (yds)
YMIN	= Minimum Y-coordinate value for barrier (yds)
ZMIN	= Minimum Z-coordinate value for barrier (yds)

R(3,IBOAT)	=	Array of three component vectors (X,Y,Z) specifying current position of IBOAT (yds)
IKIND(IBOAT)	=	Array defining the type of IBOAT 0 = Nuclear 1 = Diesel-Electric
ISNORK(IBOAT)	=	Array specifying the current snorkeling status of IBOAT 0 = Not Snorkeling 1 = Snorkeling
TSS(IBOAT)	=	Array containing the next time to start snorkeling for IBOAT (min)
TCS(IBOAT)	=	Array containing the next time to cease snorkeling for IBOAT (min)
DELT	=	Time step for the simulation (min)
IPFLAG(IBOAT)	=	Flag indicating that IBOAT has reacted to a ping by JBOAT 0 = No 1 = Yes
IPING(JBOAT)	=	Flag indicating that IBOAT has detected JBOAT's active sonar ping 0 = No 1 = Yes
TOCCUR(I,IBOAT)	=	Time when IBOAT decides to enter tactical situation I (min)
ITACT(IBOAT)	=	Current tactic employed by IBOAT for Boat No. 1: 1 = No detection has occurred 2 = Gather data 3 = Contact Lost-Patrol

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4 = Contact Lost-Chase
5 = Launch Weapon
6 = Attempt Ambush
7 = Attempt Tail-Chase
8 = Evade
9 = Close and Attack

For Boat No. 2:
1 = No detection has occurred
2 = Evade

ITBR (I,IBOAT)	= Flag indicating whether course and speed changes for tactical situation I have been carried out by IBOAT 0 = yes 1 = no
TDLY(I,IBOAT)	= Time delay before IBOAT can enter tactical situation I (min)
IDETEC(IBOAT)	= Array flag denoting whether IBOAT has detected anyone 0 = no 1 = yes
XPAT	= Array of X-coordinates for the minimum and maximum patrol points for Barrier Boat (small number first, yds)
ZS(IBOAT)	= Array of depths at which IBOAT snorkels (yds)
BS(I,IBOAT)	= A seven component vector which contains the motion parameters for each boat (see SUBSYS for definition)
CS(I,IBOAT)	= Snorkel speed of IBOAT during tactical situation I (kts)
CT(I,IBOAT)	= Normal speed of IBOAT during tactical situation I (kts)
TLSNK(IBOAT)	= Array time IBOAT last completed snorkel (min)

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PHIRHO(IBOAT,JBOAT)	=	True bearing of JBOAT relative to IBOAT (radians)
DTHET(IBOAT,JBOAT,NSYS)	=	Array of errors associated with bearing of JBOAT from the bearing subsystem NSYS on IBOAT (radians)
MOTION(IBOAT)	=	Array of tag for type of motion undergone by IBOAT (see CONTOL)
THET(IBOAT,JBOAT,NSYS)	=	Array of bearing of JBOAT from the bearing subsystem NSYS on IBOAT (radians)
ITRK	=	Tag indicating number of points in the current base course track
EDR(IBOAT,JBOAT,ISNORK)	=	IBOAT's estimate of JBOAT's detection range in the absence of any information when JBOAT is described by ISNORK (snorkeling or non-snorkeling)
IMP	=	Flag indicating whether JBOAT is snorkeling (=2) or not snorkeling (=1) when estimate of detection range is made
ESP(IBOAT,JBOAT)	=	IBOAT's estimate of JBOAT's speed in the absence of all information (kts)
MFLGTK	=	Array of flags indicating the existence of a satisfactory (=1) or unsatisfactory (=0) base course track
EWR(IBOAT,JBOAT)	=	IBOAT's estimate of JBOAT's weapon range (yds)
ZT(I,IBOAT)	=	Normal depth of IBOAT during tactical situation I (yds)

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XMAN	= Array of minimum and maximum values of the X-coordinate permitted the Barrier Boat within the barrier (smaller value first, yds)
YMAN	= Array of minimum and maximum values of the Y-coordinate permitted the Barrier Boat within the barrier (smaller value first, yds)
SNBC(I,IBOAT)	= A fraction for IBOAT representing the battery power level requiring snorkeling during tactical situation I
PI2	= 2π
PI	= π
RDOT(2,IBOAT)	= Velocity vector for IBOAT (kts)
CMAX(IBOAT)	= Array of maximum velocities for IBOAT (kts)
ETS(IBOAT)	= IBOAT's estimate of target's snorkel frequency (min)
ALFTRK	= Array of four parameters determined in TRACK ALFTRK(2) = estimated X-velocity of target (kts) ALFTRK(4) = estimated Y-velocity of target (kts)
XESTTK	= Estimate of current X-coordinate of target on his base course in barrier coordinate system (yds)
YESTTK	= Estimate of current Y-coordinate of target on his base course in barrier coordinate system (yds)

ICLASS(IBOAT)	= Flag indicating that IBOAT has (=1) or has not (=0) classified the target
MFLGFR	= Array of tracking flags for fire control system 1 = accurate track 0 = inaccurate track
DR(IBOAT,JBOAT,NSYS)	= Range from JBOAT to IBOAT reported by ranging system NSYS on JBOAT (yds)
WRMAX(IBOAT)	= Maximum weapon range of IBOAT (yds)
RELB(IBOAT,JBOAT)	= Actual relative bearing of JBOAT with respect to IBOAT (radians)
ISEAS	= Sea State
RHO(IBOAT,JBOAT)	= Range of JBOAT from IBOAT (yds)
CMIN(I,IBOAT)	= Array of minimum speeds for each boat (kts)
ZLIM(I,JBOAT)	= A two component vector for JBOAT defining operating depths I = 1 Minimum depth (yds) I = 2 Maximum depth (yds)
STN(IBOAT,JBOAT,NSYS)	= Signal-to-noise ratio at IBOAT with system NSYS from target JBOAT (dB)
IFIR	= Number of points in fire control track
XESTFR	= Fire control estimate of X-coordinate of target on his current course in the barrier coordinate system (yds)
YESTFR	= Fire control estimate of Y-coordinate of target on his current course in the barrier coordinate system

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EDR1(IBOAT,JBOAT)	=	IBOAT's estimate of JBOAT's detection radius for use in time to shoot determination (yds)
EWR1(IBOAT,JBOAT)	=	IBOAT's estimate of JBOAT's weapon range for use in time to shoot determination (yds)
RFIRE(IBOAT)	=	Maximum range at which IBOAT will launch his weapon (yds)
BLIND(I,IBOAT)	=	Array for IBOAT of blind spot angles (radians)
ESCAPE	=	The distance from the boundary beyond which the Penetrator has definitely escaped the Barrier Boat (yds)
PHIO2(IBOAT)	=	Basic heading of IBOAT (radians)
TTURN	=	Time for Penetrator to execute next turn (min)
JEY	=	Array of random number keys
BATLVI	=	Current battery level of Boat 1
PHI2	=	True bearing (with error) reported by bearing subsystem used in tactical situation 2 (TS2)
DTSAVE	=	Last error in bearing reported by bearing subsystem (radians)
RSAVE2	=	Last range reported by ranging subsystem for TS2 (yds)
TSAVE2	=	Time tag for RSAVE2
RTEST	=	Estimate of Range to target boat (yds)
IXGO2	=	Tag used to indicate whether Barrier Boat hits boundary (=2) in tactical situation 2 or not (=1)

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VC4	=	Velocity for Barrier Boat in TS4 (kts)
VC6	=	Velocity for Barrier Boat in proceeding to ambush as returned by SSAMB or SSNAMB. As an input to these routines it is the minimum speed at which the boats proceed to ambush (kts)
ALF	=	Heading Barrier Boat assumes when he reaches ambush position (radians)
BETA	=	Angle through which Barrier Boat must turn to proceed to ambush (radians)
TWAIT	=	Length of time Barrier Boat can wait at ambush position before target enters his detection radius (min)
PHI6	=	Last true bearing (with error) from the bearing subsystem used in TS 6
RSAVE6	=	Last range from the ranging subsystem used in TS 6
TSAVE6	=	Time tag for PHI6 and RSAVE6
PHI99	=	Last true bearing of target from bearing subsystem (with error) used in TS 9
RSAVE9	=	Last range from ranging subsystem used in TS 9
TSAVE9	=	Time tag for PHI99 and RSAVE9
PHI7	=	Last true bearing of target (with error) from bearing subsystem used in TS 7

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RSAVE7	= Last range reported by the ranging subsystem used in TS7
TSAVE7	= Time tag for PHI7 and RSAVE9
R12	= Current range to target used in TS5 (yds)
XPAT3	= Array of patrol limits on the X-coordinate of the Barrier Boat used in TS3 (smallest value first, yds)
CSAVE6	= Estimate of target velocity from TRACK used in TS6 (kts)
IXGO6	= Tag used to indicate whether Barrier Boat has lost contact (=2) or not (=1) with target in TS6
SNAV(IBOAT,JBOAT,I)	= For each boat array of average signal-to-noise used in probability of detection portion of SUBSYS
PD(IBOAT,JBOAT,I)	= Probability that IBOAT with system I detects JBOAT
ISTART(IBOAT)	= For each boat flag to indicate whether IBOAT must restart detection process
NTIME(IBOAT)	= For each boat number of points currently in S/N table for detection
DETLM(IBOAT)	= For each boat lower limit for probability of detection
NLOSS(IBOAT)	= For each boat number of consecutive time steps for which detection has been lost
IMCC(IBOAT)	= Flag indicating that IBOAT has completed a major course change

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MCC(IBOAT)	=	Number of time steps after IBOAT's course change that the other boat realizes a major course change has occurred
JTS6	=	Flag to indicate possible action upon arrival at ambush position by Barrier Boat
IXGO8	=	Tag used to indicate whether Barrier Boat hits boundary (=2) or not (=1) in TS8
JTACT	=	Flag indicating that simulation is completed
BATLV2	=	Current battery level of Boat 2
ISYSON(IBOAT,NSYS)	=	Array for each boat and subsystem indicating status of subsystem 0 = Off 1 = On
Y1	=	Dummy variable
Y2	=	Dummy variable
FX2	=	Range used to calculate estimated range to target (yds)
TX2	=	Time used to calculate estimated range to target (min)
THX2	=	Last bearing from the bearing subsystem in TS2
RSAVE3	=	Estimate of target's range when contact was lost (yds)
XLIM3	=	Used to readjust patrol path as Barrier Boat moves a distance XLIM3 from the line he estimates the other boat is taking (yds)
PH14	=	Last true bearing to be used in TS4

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RHOVEC	=	Vector of target's coordinates (X,Y,Z) with respect to own ship
RVEC	=	Vector of target's coordinates (X,Y,Z) in barrier coordinate system
VVEC	=	Estimate of target's velocity vector (V_X, V_Y, V_Z) in knots
TTESTT	=	Estimated time from present when target will snorkel (min)
CMAX6	=	Maximum speed of Barrier Boat proceeding to ambush (kts)
JAMB	=	Flag indicating ambush can (=0) or cannot (=1) be made
TSTOP	=	Time from beginning of intercept when Barrier Boat reaches ambush position (min)
X9	=	Estimate of current X-coordinate of target used in TS9
Y9	=	Estimate of current Y-coordinate of target used in TS9
CX9	=	Estimate of current velocity of target used in TS9
PH19	=	Heading of other boat
C9	=	Normal speed of Barrier Boat during close and attack, TS9 (kts)
PHIR9	=	Last true bearing of target from bearing subsystem (with error) for use in TS9
PK	=	Probability of Kill in TS5 (only zero value is contained in this program as CHOICE IIB calculates PK)
THX7	=	Last bearing from the bearing subsystem in TS7

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CTEST7	= Current estimate of target's velocity along his base course (kts)
MTK	= Redetection flag

Threshold for detection with AN/BQR-2 (DIMUS) is a signal-to-noise of -33.3 dB

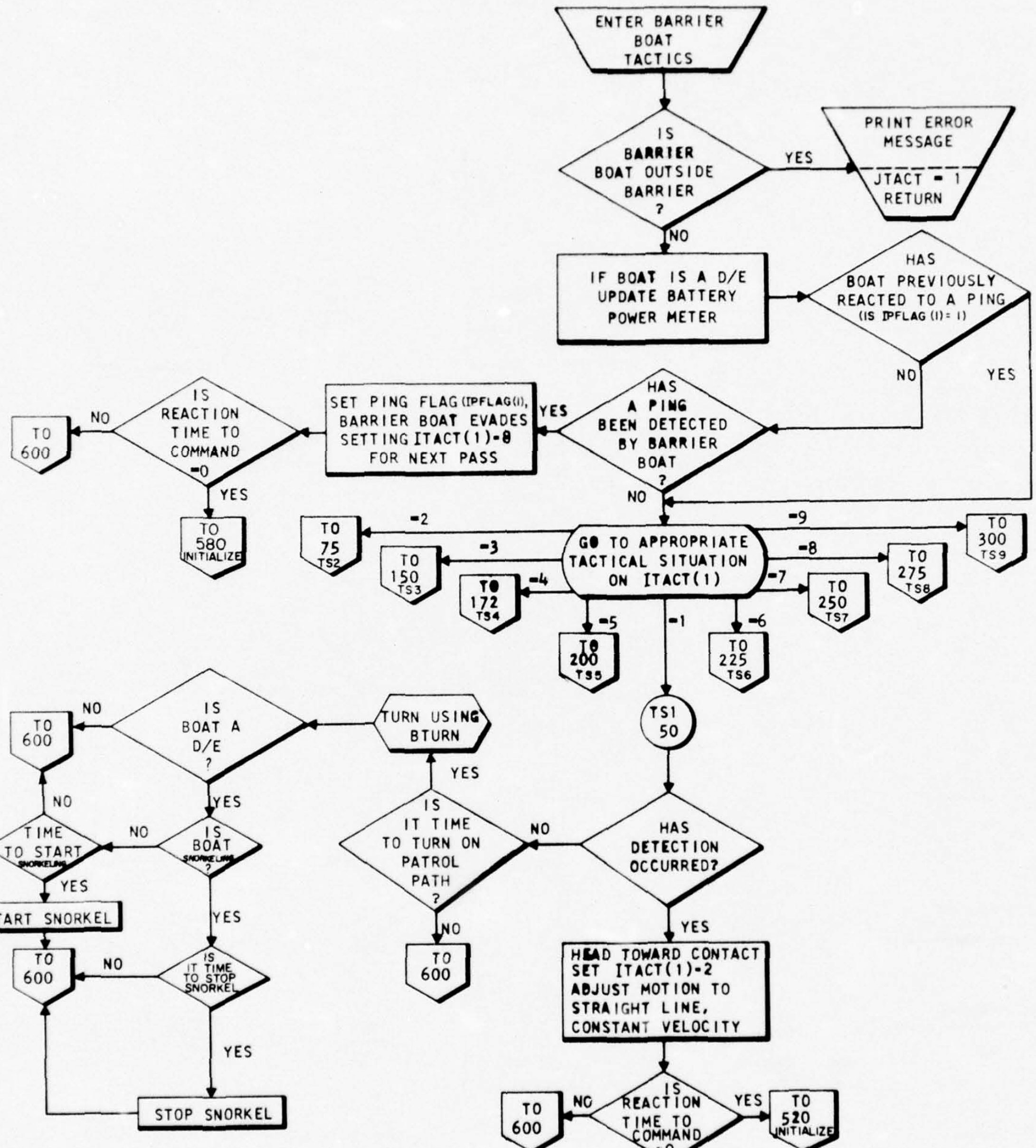

FIG. A-18 – TACTIC FLOW CHART (PART I)

TRACOR, INC DWG B6-62-281
AUSTIN, TEXAS 8-1-67 WEIDMAN

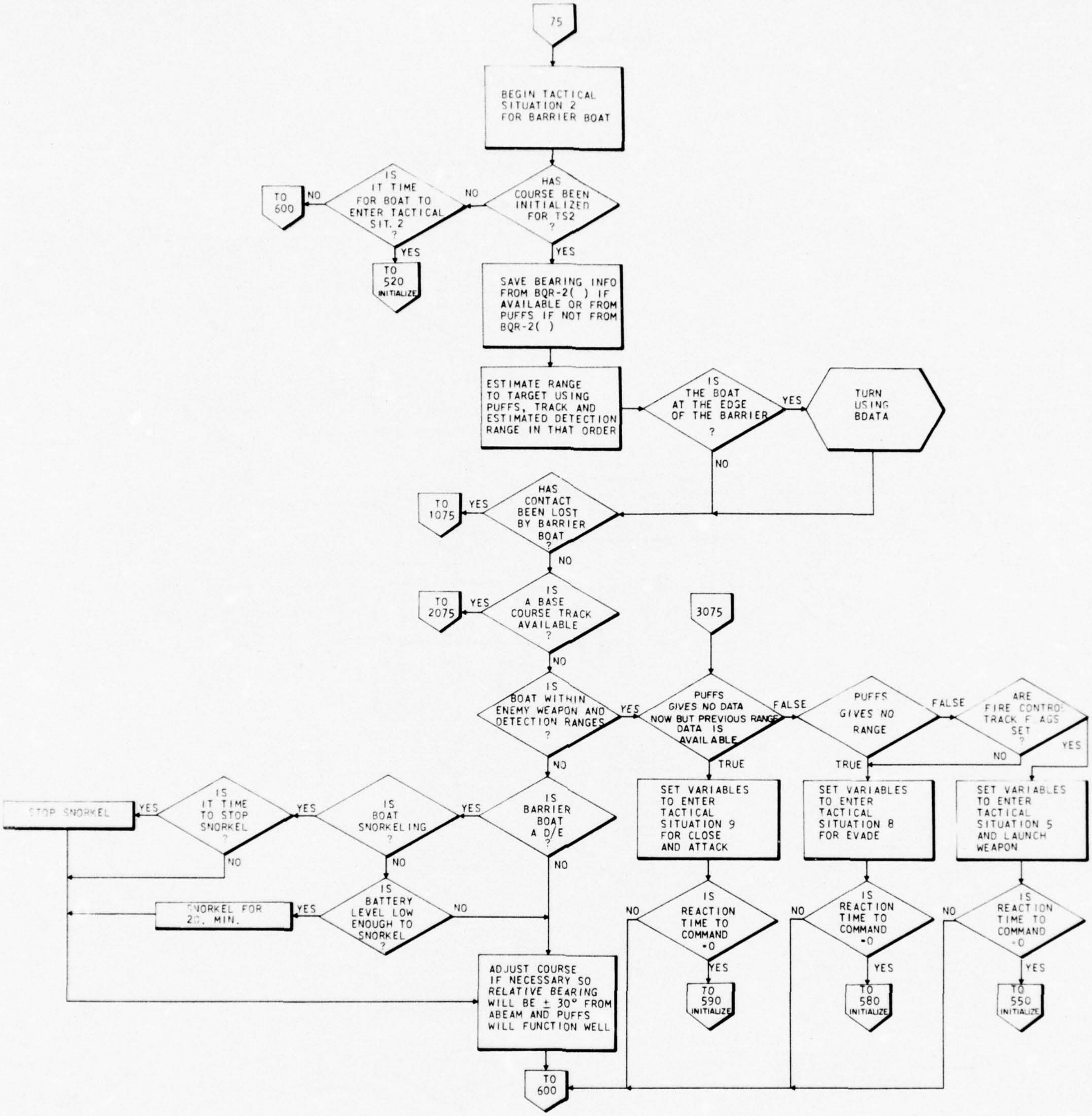

FIG. A-18 – TACTIC FLOW CHART (PART 2)

TRACOR, INC DWG C6-62-265
AUSTIN, TEXAS 5-2-67 WEIDMAN

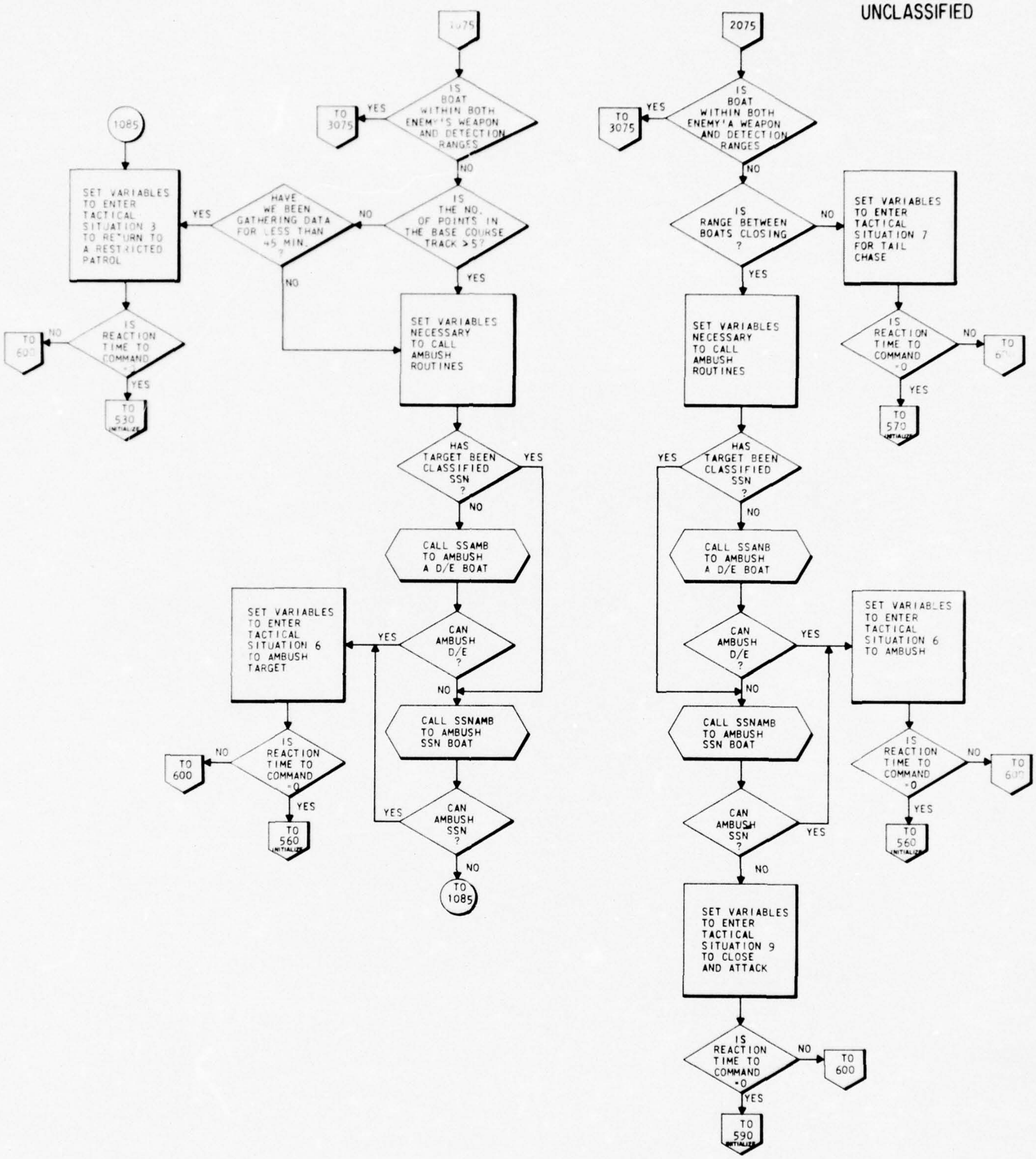

FIG. A-18 -TACTIC FLOW CHART (PART 3)

TRACOR, INC DWG 06-62-268
AUSTIN, TEXAS 8-2-67 WEIDMAN

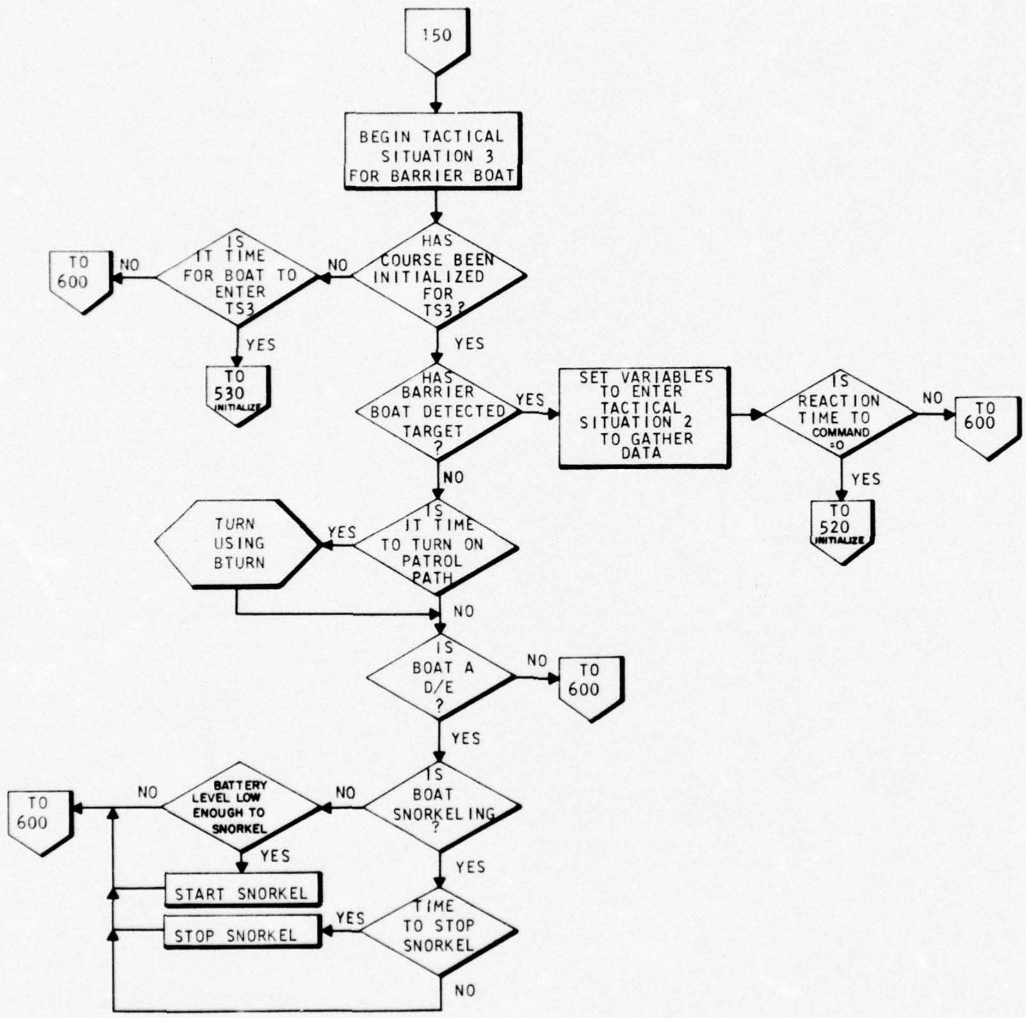

FIG. A-18 - TACTIC FLOW CHART (PART 4)

TRACOR, INC DWG 86-62-280
AUSTIN, TEXAS 5-1-67 WEIDMAN

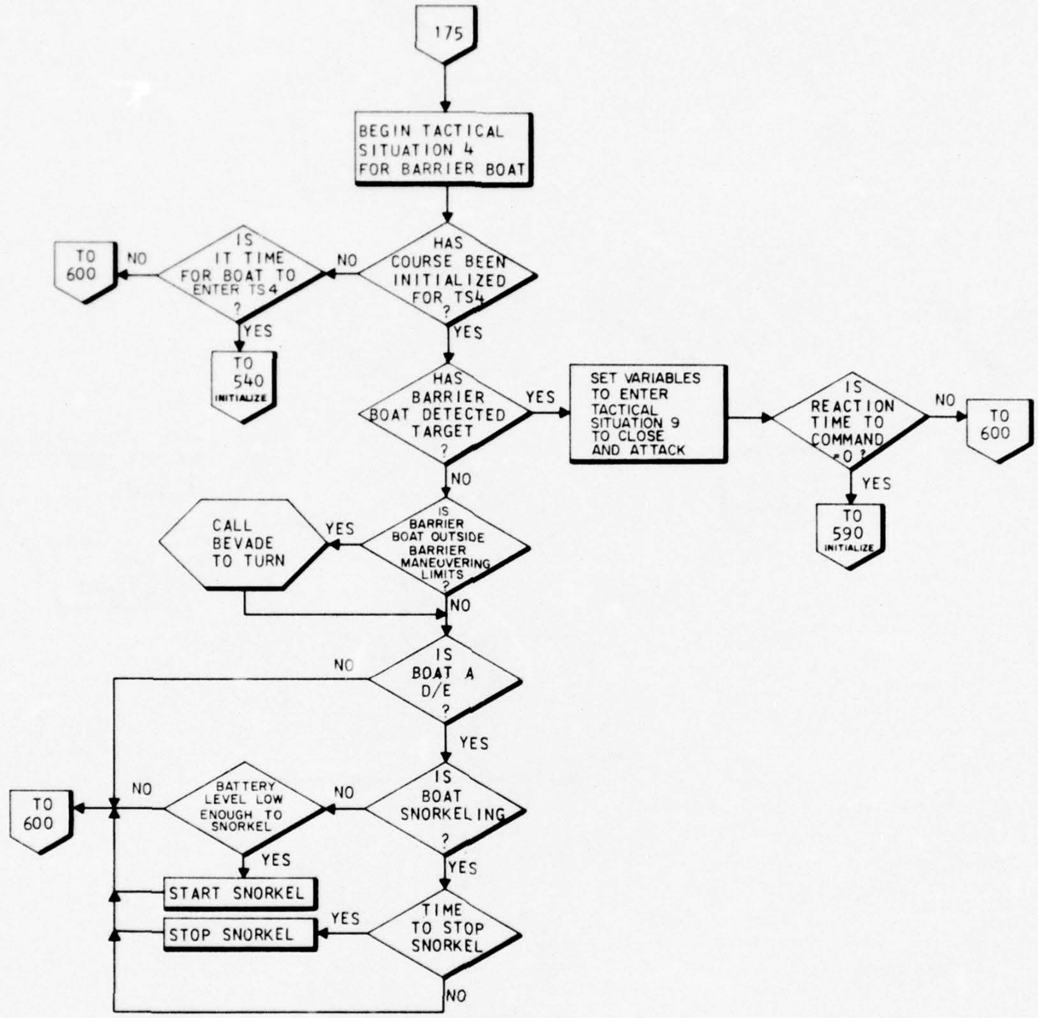

FIG. A-18 - TACTIC FLOW CHART (PART 5)

TRACOR, INC DWG B6-62-279
AUSTIN, TEXAS 5-1-67 WEIDMAN

UNCLASSIFIED

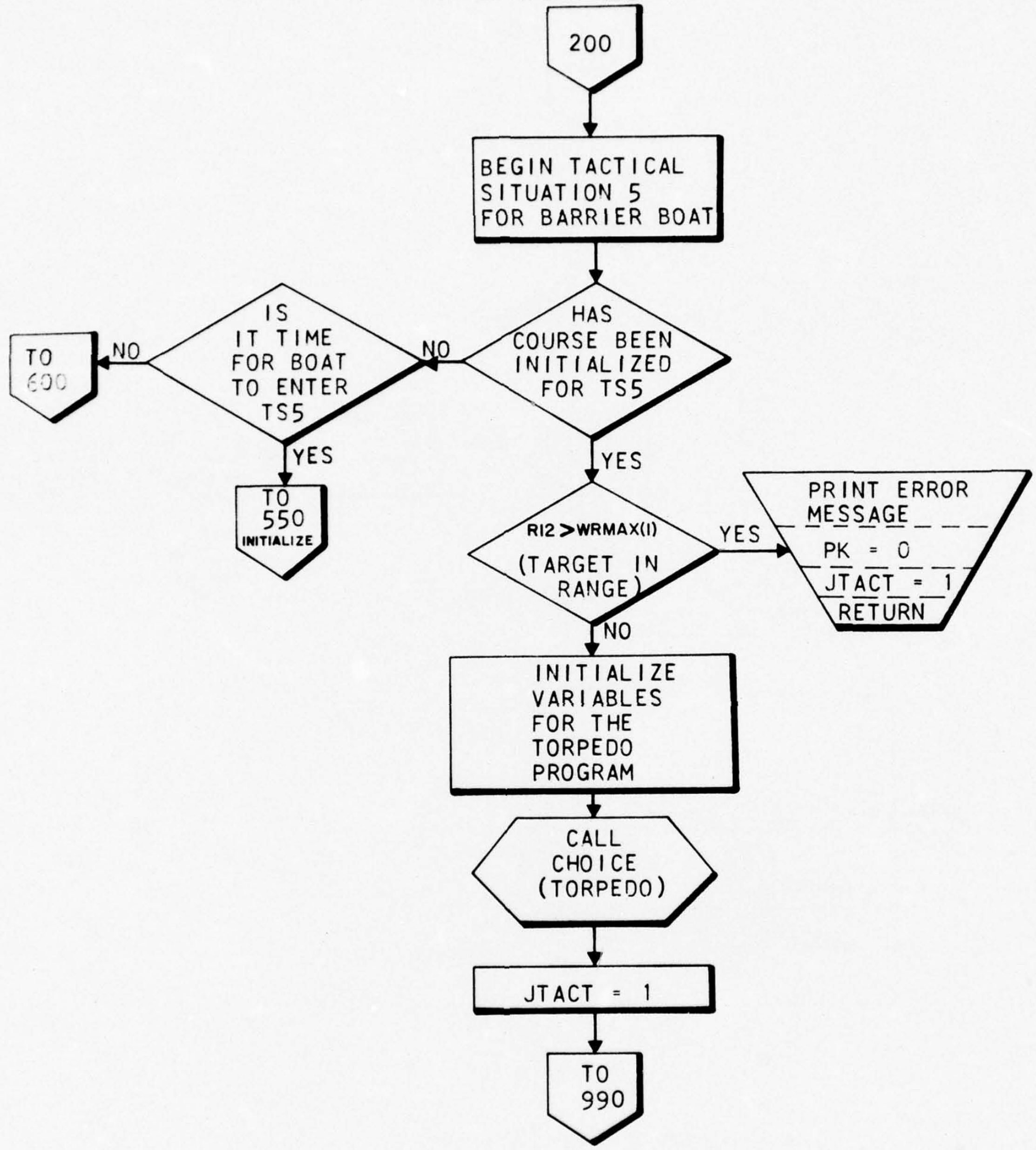

FIG. A-18 – TACTIC FLOW CHART (PART 6)

UNCLASSIFIED

TRACOR, INC. DWG. A6-62-275
AUSTIN, TEXAS 5-1-67 WEIDMAN

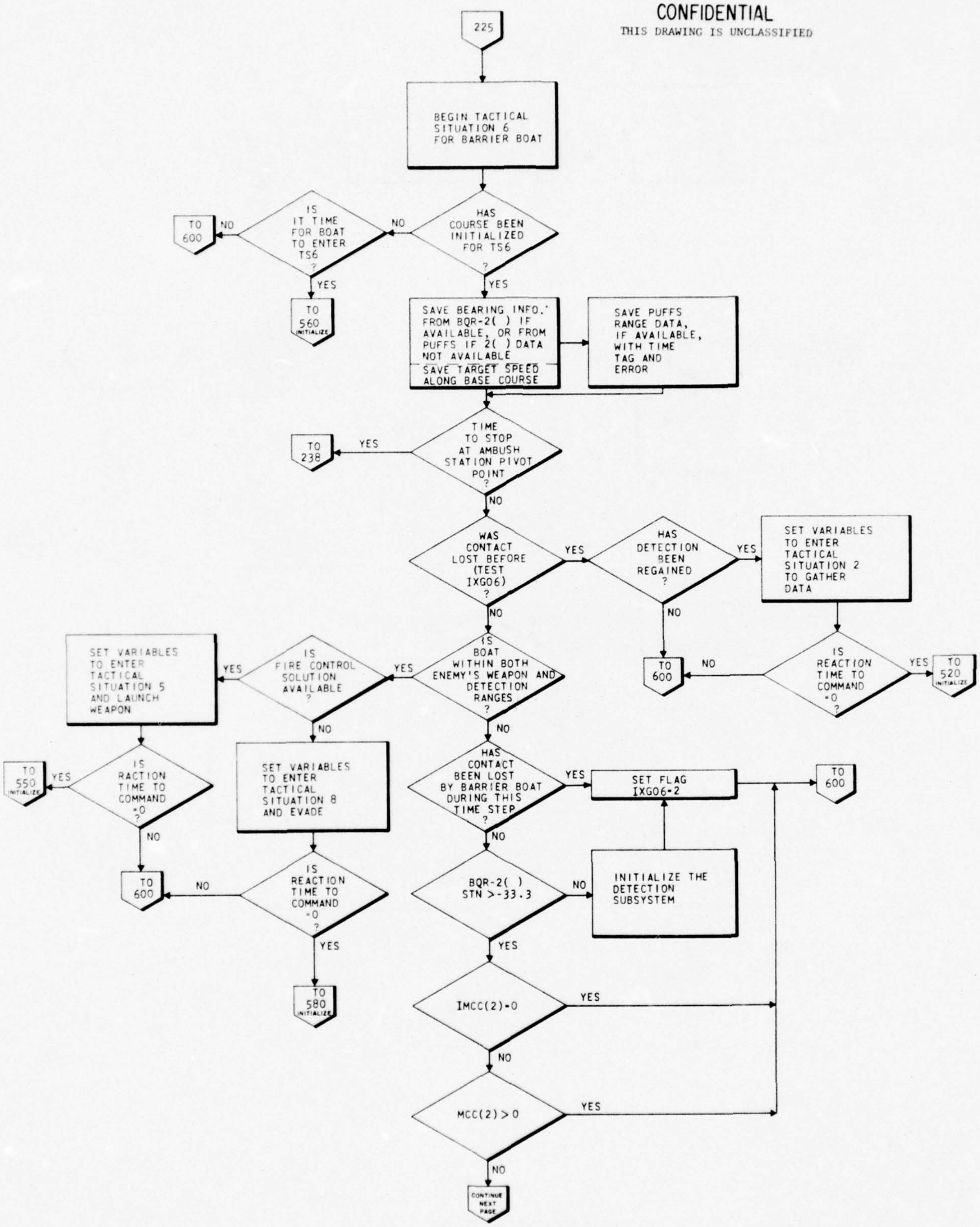

FIG. A-18 —TACTIC FLOW CHART (PART 7)

TRACOR, INC. DWGC6-62-262
AUSTIN, TEXAS 5-2-67 WEIDMAN

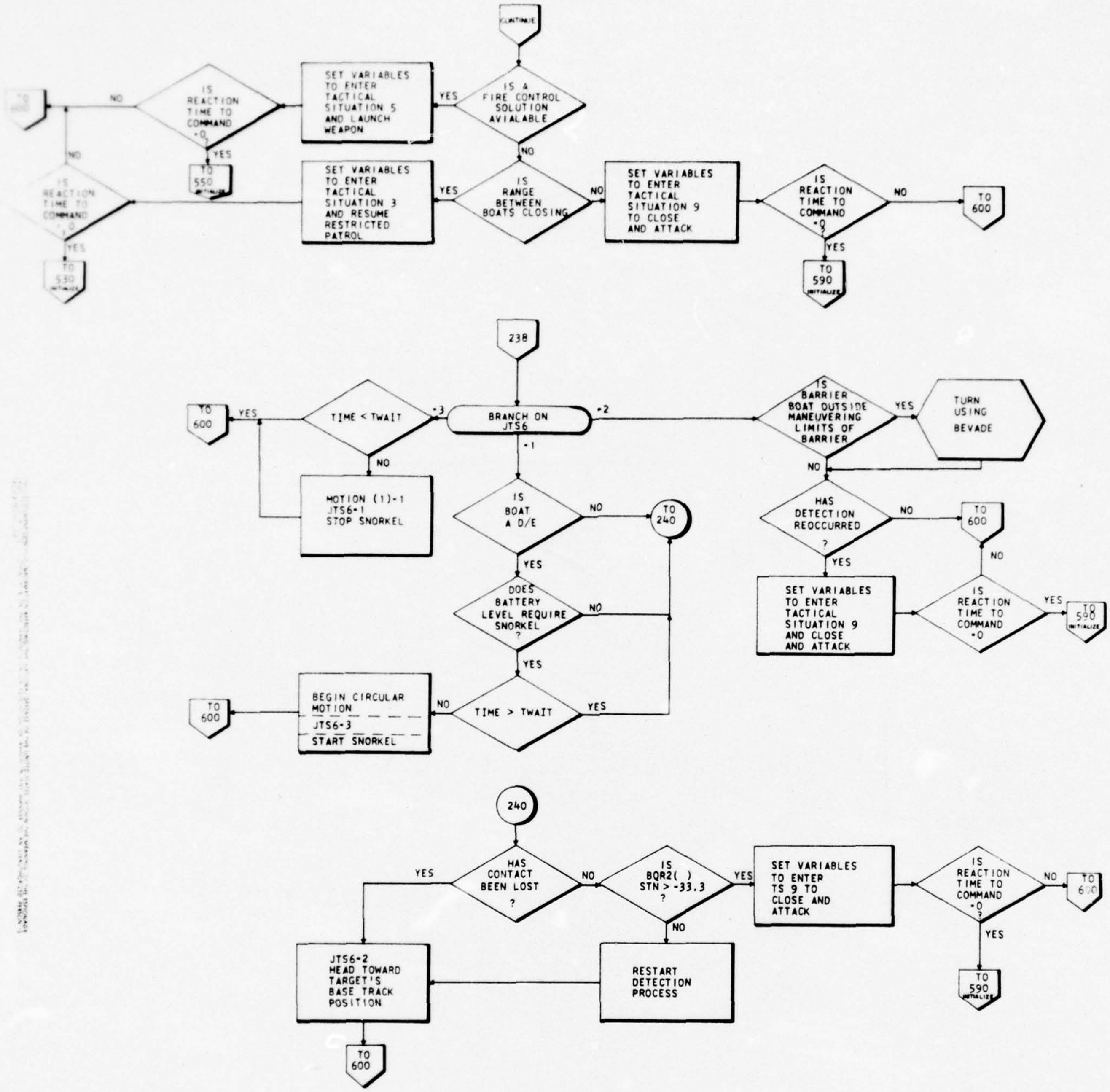

FIG. A-18 – TACTIC FLOW CHART (PART 8)

TRACOR, INC DWG C6-62-286
AUSTIN, TEXAS 5-2-67 WEIDMAN

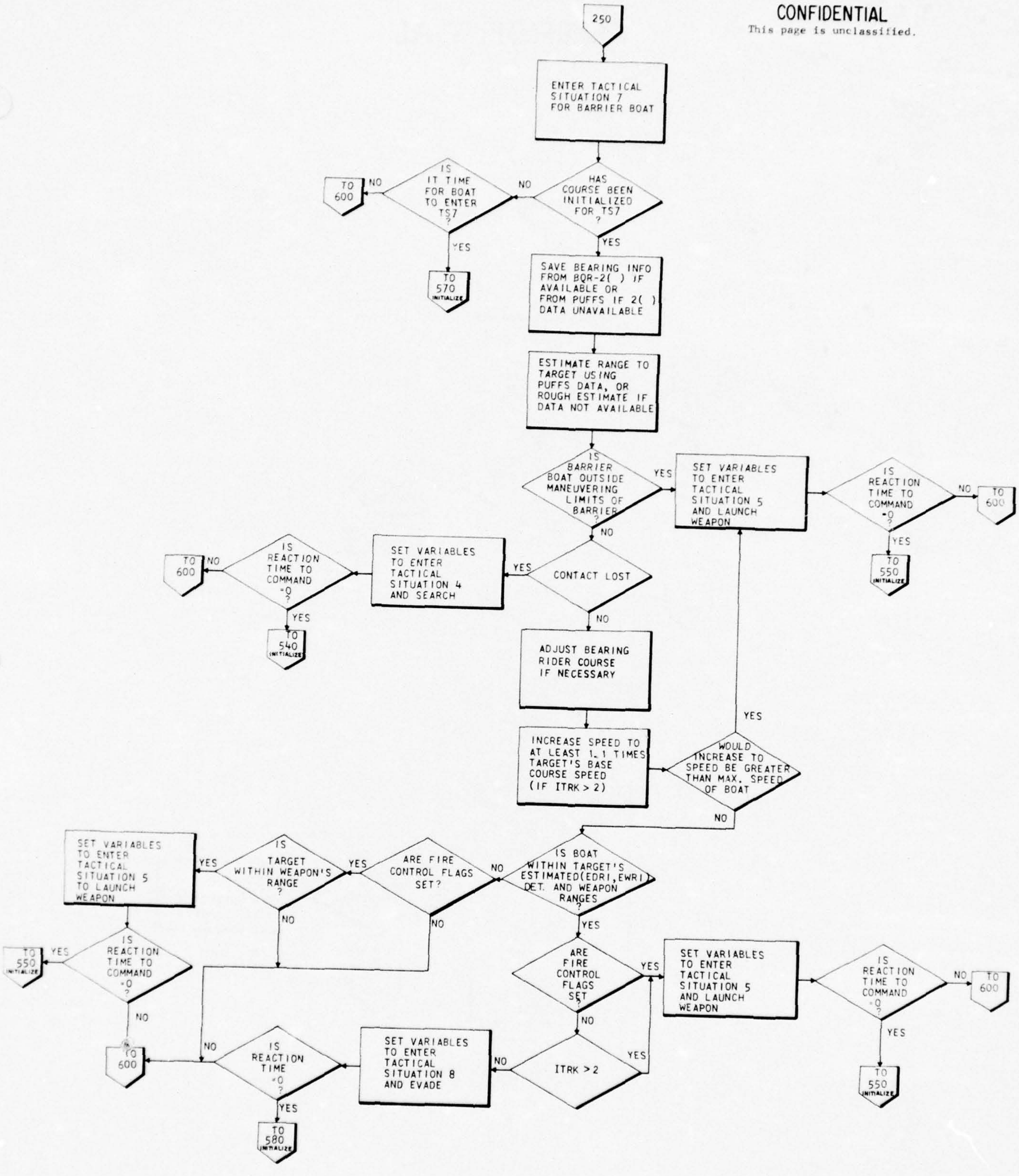

FIG. A-18 — TACTIC FLOW CHART (PART 9)

TRACOR, INC DWG C6-62-260
AUSTIN, TEXAS 3-3-67 WEIDMAN

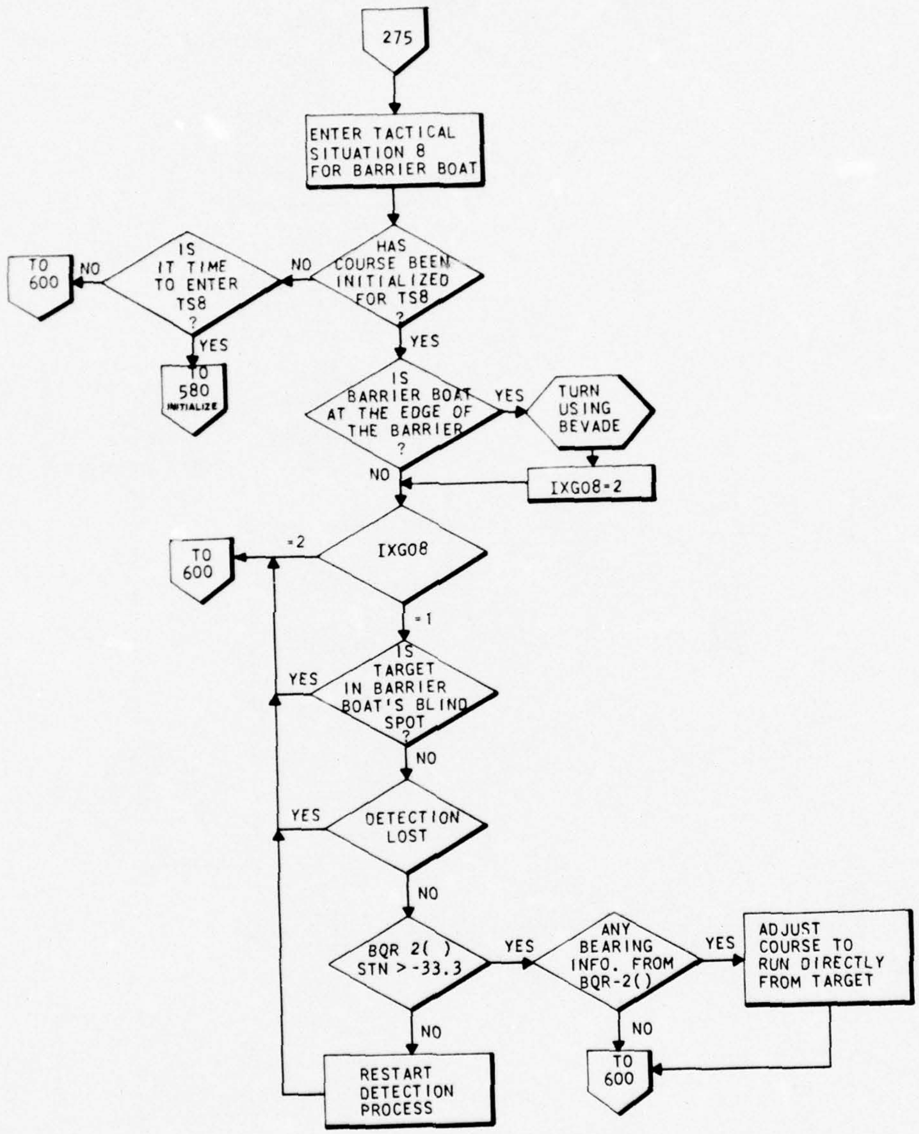

FIG. A-18 -TACTIC FLOW CHART (PART 10)

TRACOR, INC DWG B6-62-284
AUSTIN, TEXAS 4-28-67 WEIDMAN

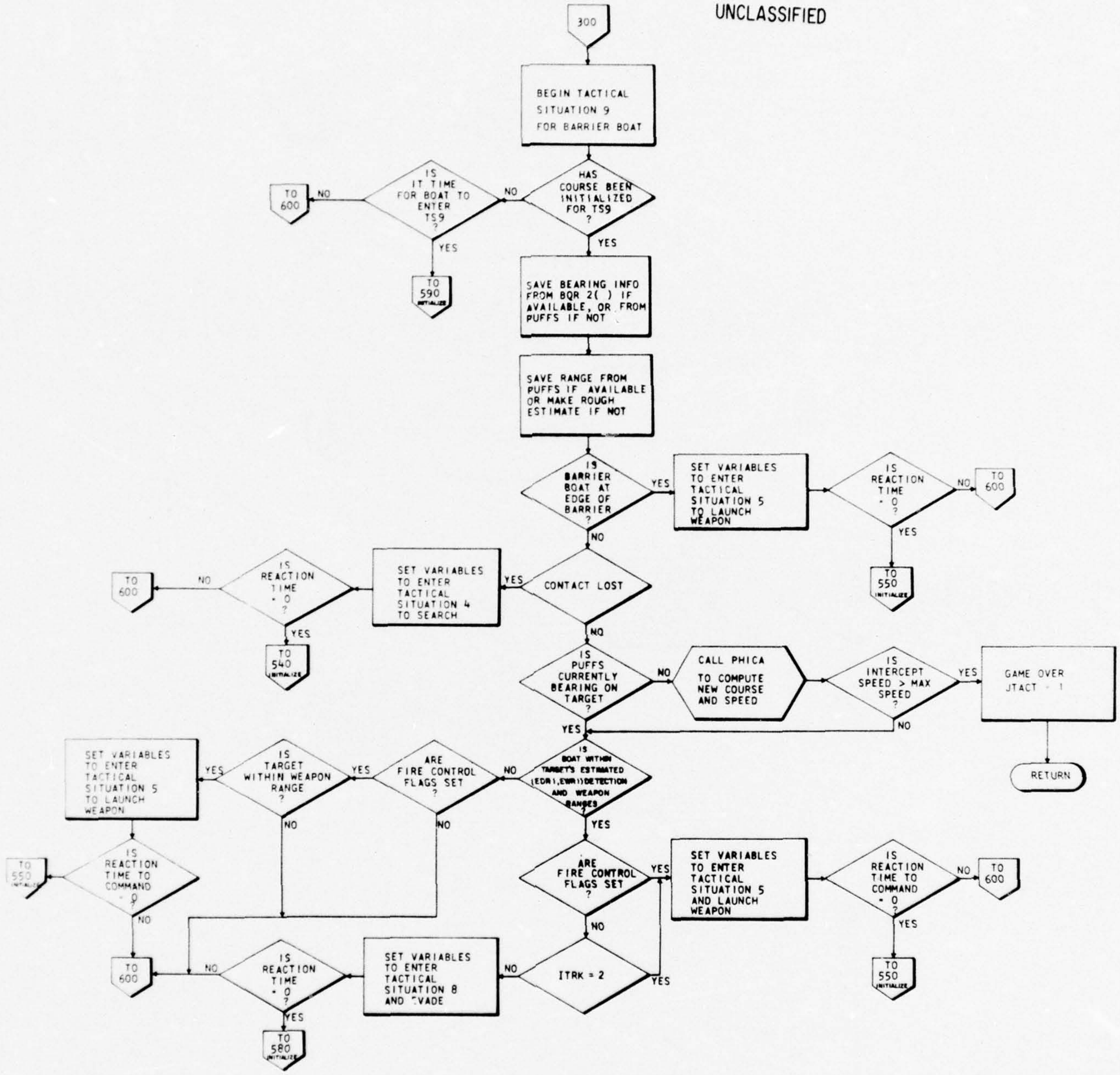

FIG. A-18 — TACTIC FLOW CHART (PART II)

TRACOR, INC DWG C6-62-267
AUSTIN, TEXAS 8-8-67

UNCLASSIFIED

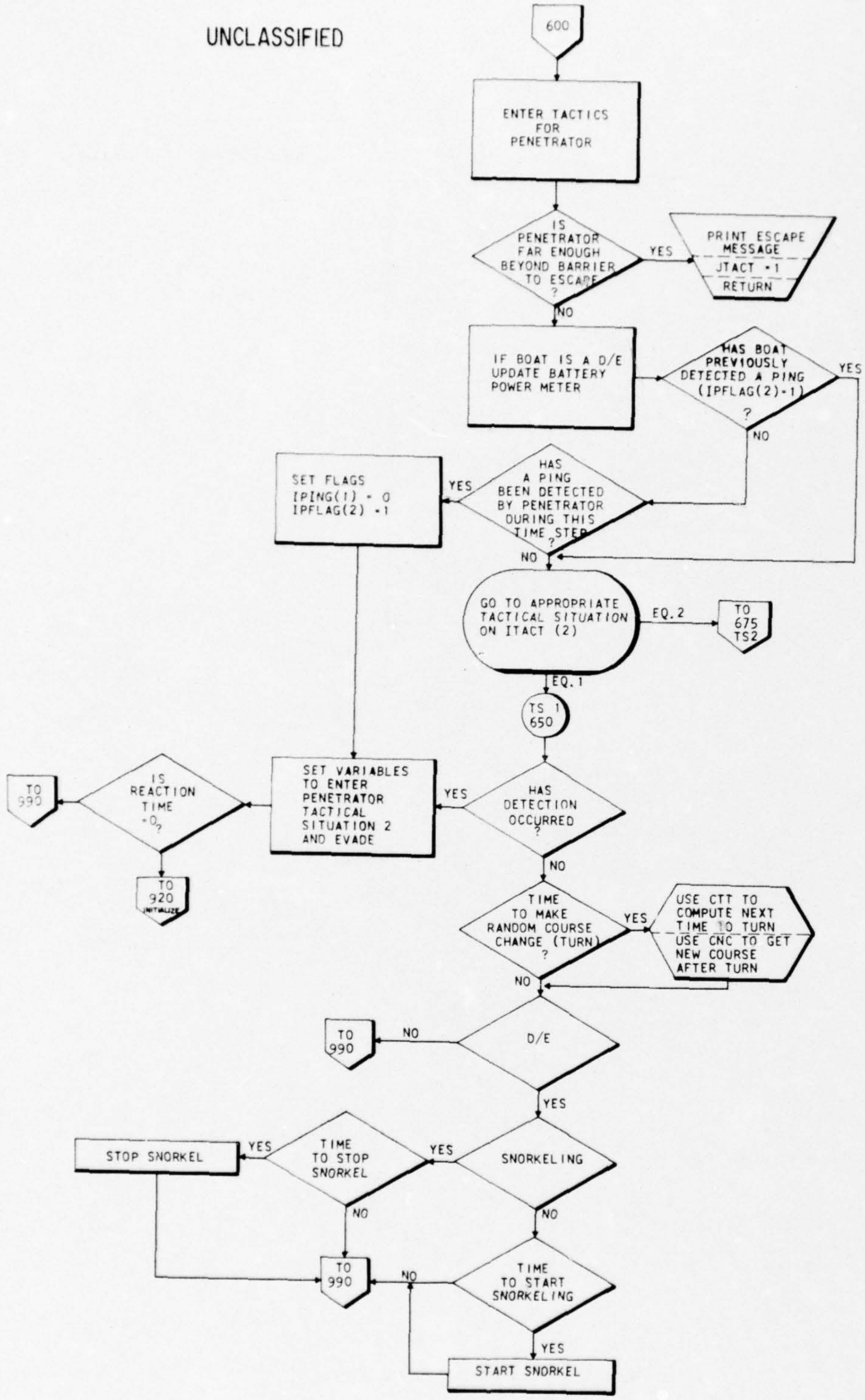

FIG. A-18 -TACTIC FLOW CHART (PART 12)

UNCLASSIFIED

TRACOR, INC DWG C6-62-284
AUSTIN, TEXAS 5-2-67 WEIDMAN

CONFIDENTIAL

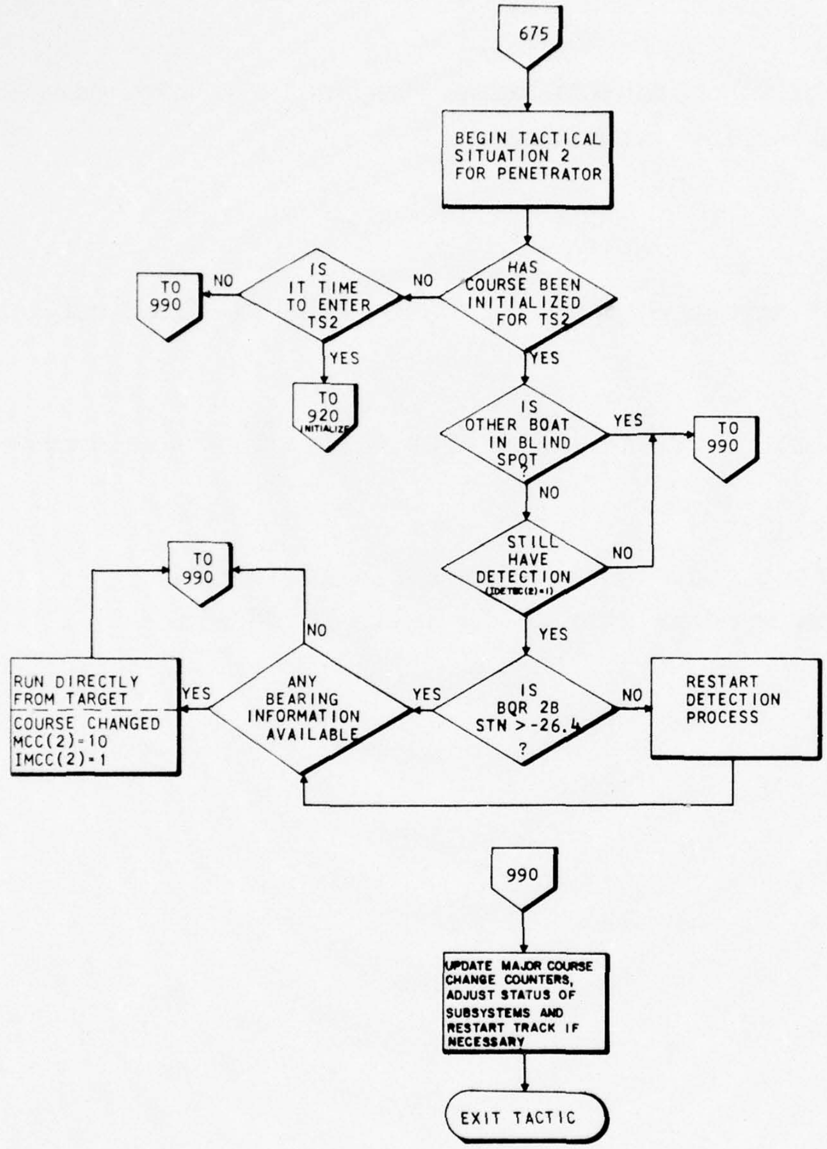

FIG. A-18 - TACTIC FLOW CHART (PART 13)

CONFIDENTIAL

TRACOR, INC DWG B6-62-287
AUSTIN, TEXAS 5-2-67 WEIDMAN

TRACOR 6500 TRACOR LANE, AUSTIN, TEXAS 78721

ATCS

PURPOSE: This function subprogram computes the next time to cease snorkeling for each boat.

INPUT:

T = Time

I = Number of boat for which ATCS is to be computed

OUTPUT:

Value of the function ATCS = Time to cease snorkeling

INTERNAL CONSTANTS:

Boat 1 stops snorkeling again in 20 min

Boat 2 stops snorkeling again in 35 min

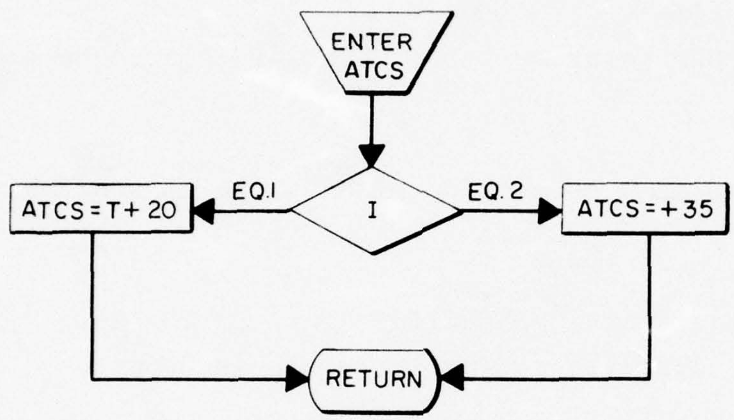

FIG. A-19 – ATCS FLOW CHART

TRACOR, INC. DWG. A6-62-258
AUSTIN, TEXAS 4·21·67 WEIDMAN/SL

TRACOR 6500 TRACOR LANE, AUSTIN, TEXAS 78721

ATSS

PURPOSE: This function subprogram computes the next time to start snorkeling for each boat.

INPUT:

T = Time

I = Number of boat for which ATSS is to be computed

OUTPUT:

Value of the function ATSS = Time to start snorkeling

INTERNAL CONSTANTS:

Boat 1 starts snorkeling again in 20 min.

Boat 2 starts snorkeling again in 30 min.

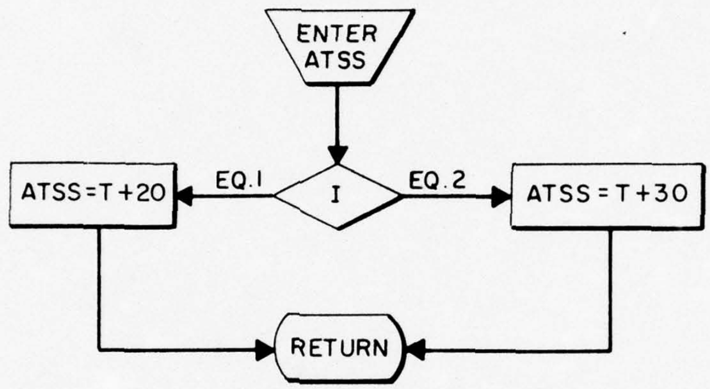

FIG. A-20 — ATSS FLOW CHART

TRACOR, INC. DWG. A6-62-257
AUSTIN, TEXAS 4·21·67 WEIDMAN/SL

TRACOR 6500 TRACOR LANE, AUSTIN, TEXAS 78721

BATL1

PURPOSE: This routine is designed to compute the battery level at each time step for the Barrier Boat. The routine has a branch determined by whether or not the Barrier Boat is snorkeling. Currently the routine is a dummy; the battery level is set to 1.0 each time.

TRACOR 6500 TRACOR LANE, AUSTIN, TEXAS 78721

BATL2

PURPOSE: This routine computes the battery level for the Penetrator Boat at each time step, branching on whether that boat is or is not snorkeling. The routine is currently a dummy; the battery level is always set to 1.0 at each time step.

TRACOR 6500 TRACOR LANE, AUSTIN, TEXAS 78721

BDATA

PURPOSE: This routine handles the case in which the Barrier Boat is specularly reflected (angle of incidence equal angle to reflection) from the barrier.

INPUT:

X = Current X-coordinate of Barrier Boat
Y = Current Y-coordinate of Barrier Boat
XL = Lower limit for X-coordinate inside barrier
XH = Upper limit for X-coordinate inside barrier
YL = Lower limit for Y-coordinate inside barrier
YH = Upper limit for Y-coordinate inside barrier
PHIT = True bearing of target from Barrier Boat
PHI = Current heading of Barrier Boat

OUTPUT:

PHI = New course for Barrier Boat
X = New X-position of Barrier Boat
Y = New Y-position of Barrier Boat

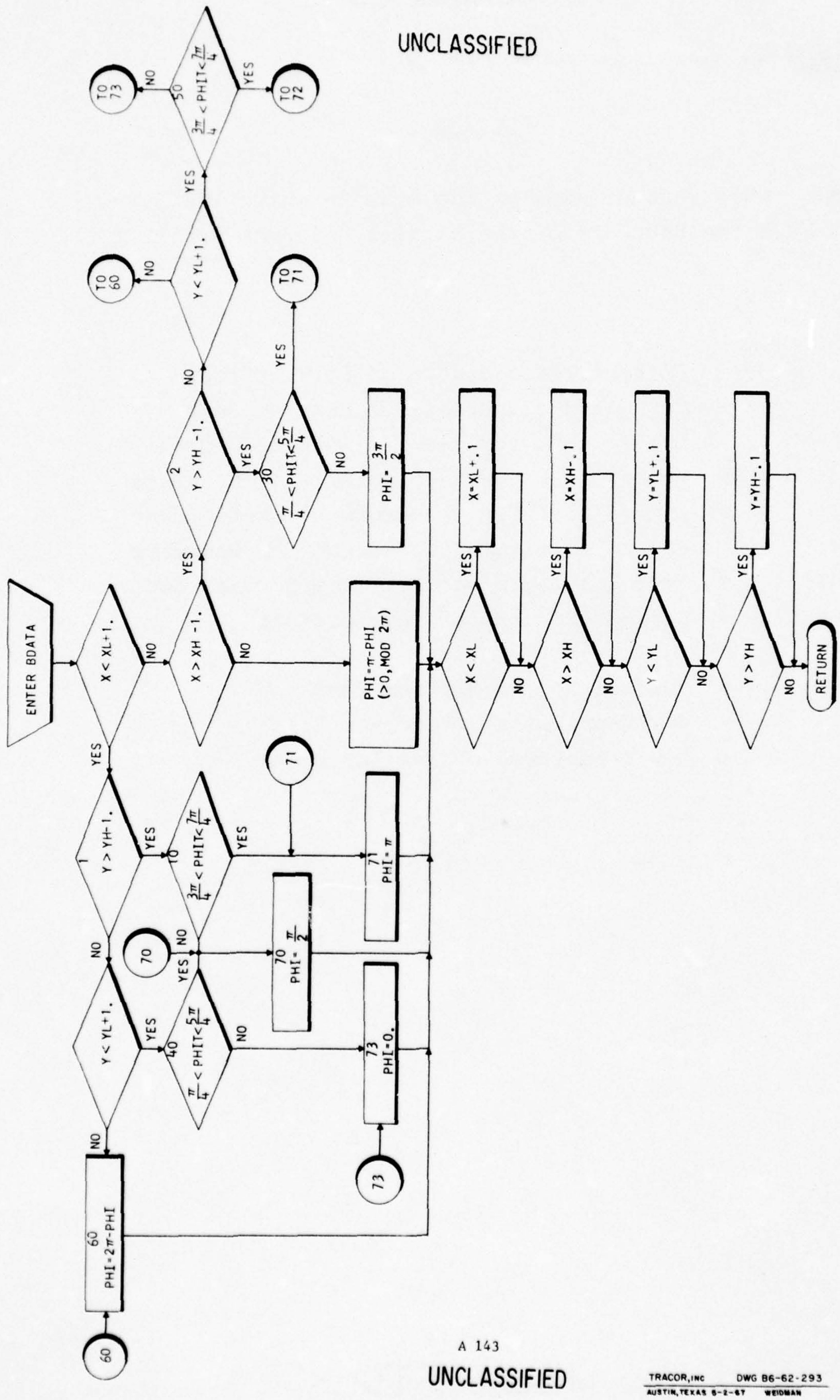

FIG. A-21 — BDATA FLOW CHART

TRACOR, INC DWG B6-62-293
AUSTIN, TEXAS 6-2-67 WEIDMAN

TRACOR 6500 TRACOR LANE, AUSTIN, TEXAS 78721

BEVADE

PURPOSE: This routine handles the case in which the Barrier Boat strikes the boundary of the barrier and runs parallel to it.

INPUT:

X	=	Current X-coordinate of Barrier Boat
Y	=	Current Y-coordinate of Barrier Boat
XL	=	Lower limit for X-coordinate of boundary
XH	=	Upper limit for X-coordinate of boundary
YL	=	Lower limit for Y-coordinate of boundary
YH	=	Upper limit for Y-coordinate of boundary
PHIT	=	True bearing of target from Barrier Boat
PHI	=	Current heading of Barrier Boat

OUTPUT:

PHI	=	New course for Barrier Boat
X	=	New X-position of Barrier Boat
Y	=	New Y-position of Barrier Boat

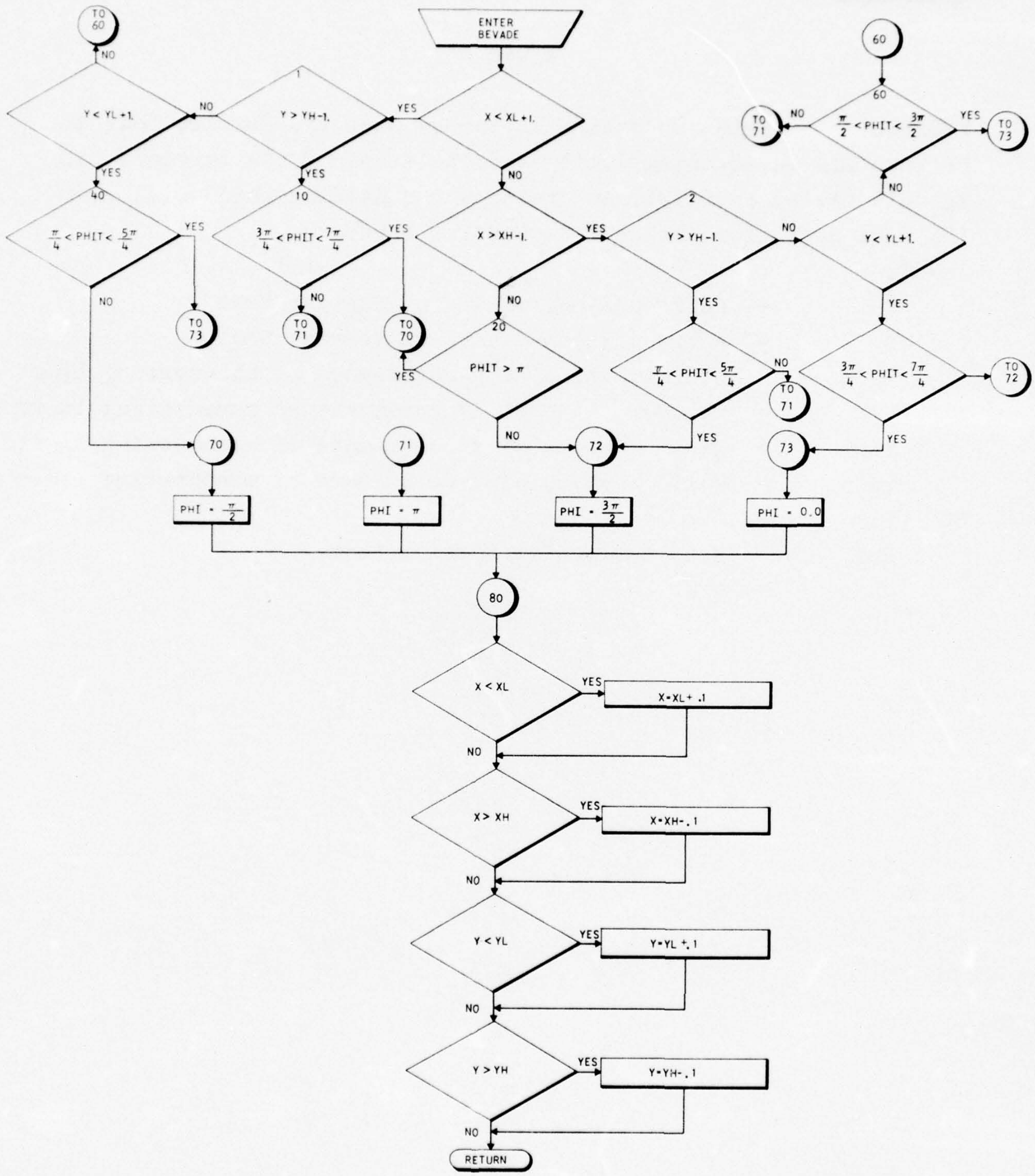

FIG. A-22- BEVADE FLOW CHART

TRACOR, INC DWG C6-62-300
AUSTIN, TEXAS 5-2-67 WEIDMAN

TRACOR 6500 TRACOR LANE, AUSTIN, TEXAS 78721

BTURN

PURPOSE: This subroutine is called when the Barrier Boat is between its maneuvering limits and the sides of the barrier. It is only called from TS1, and returns the heading which will move the boat away from the nearest barrier boundary.

INPUT:

X	=	Current X-coordinate of Barrier Boat
Y	=	Current Y-coordinate of Barrier Boat
X1	=	Minimum value of X-coordinate of maneuvering limit
X2	=	Maximum value of X-coordinate of maneuvering limit
Y1	=	Minimum value of Y-coordinate of maneuvering limit
Y2	=	Maximum value of Y-coordinate of maneuvering limit

OUTPUT:

PHI	=	New heading for Barrier Boat

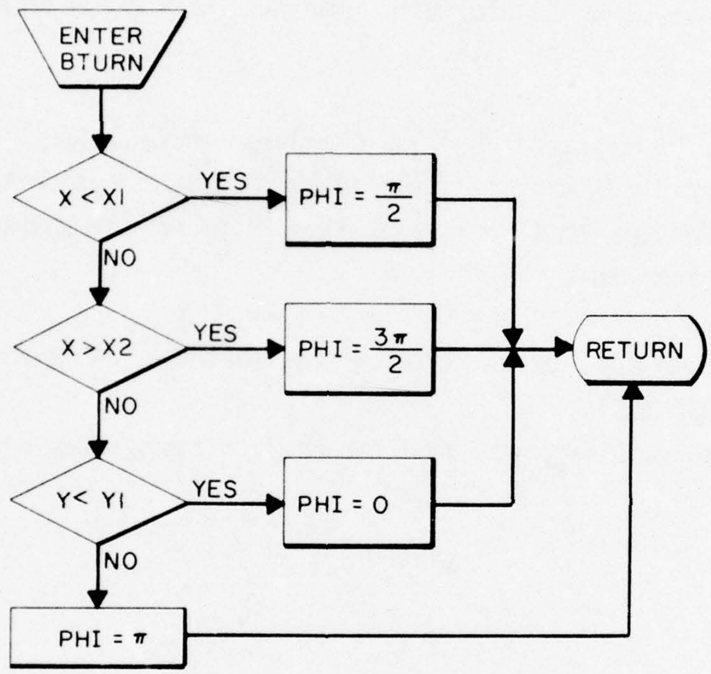

FIG. A-23 — BTURN FLOW CHART

TRACOR, INC. AUSTIN, TEXAS
DWG. A6-62-259
4·21·67 WEIDMAN/SL

TRACOR 6500 TRACOR LANE, AUSTIN, TEXAS 78721

CCHG

PURPOSE: This function computes the course required for the Barrier Boat so that a contact at the apparent true bearing (A+E) bears ±D relative. A is the true bearing and E is the true bearing error.

A = True bearing of target (without error)

E = Error in bearing reported by bearing subsystem

D = Angle target is to make from bow on new course of Barrier Boat

OUTPUT:

Value of the function CCHG = New heading of Barrier Boat

INTERNAL VARIABLES:

T = True bearing returned by the bearing subsystem (with error)

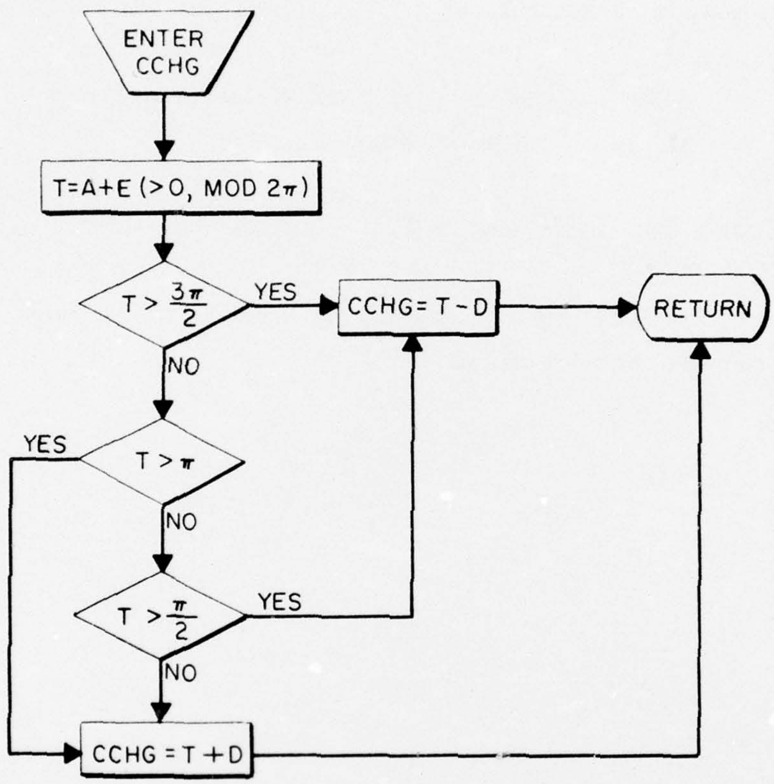

FIG. A-24 — CCHG FLOW CHART

TRACOR, INC. DWG. A6-62-256
AUSTIN, TEXAS 21-67 WEIDMAN/SL

TRACOR 6500 TRACOR LANE, AUSTIN, TEXAS 78721

CNC

PURPOSE: This function computes the new heading for the Penetrator by adding a randomly chosen angle within given limits to that boat's basic heading.

INPUT:

PHI = Base course heading of ship (radians)

KEY = Array of random numbers

OUTPUT:

Value of the function CNC = New heading of boat

INTERNAL CONSTANTS:

The current limits on the maneuver are that it must be between $\pm 20^{\circ}$ of the base course.

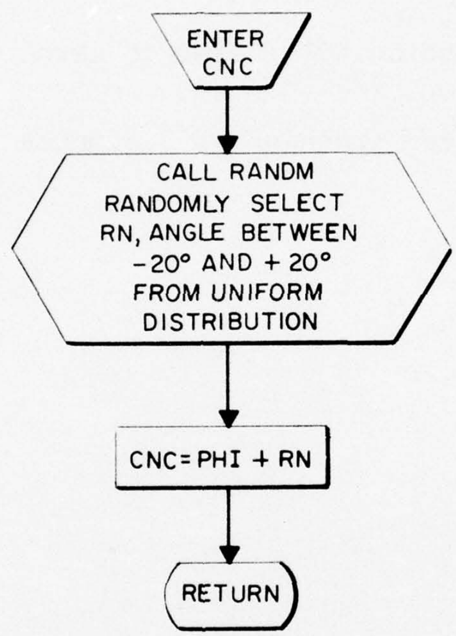

FIG. A-25 -CNC FLOW CHART

TRACOR, INC. DWG. A6-62-255
AUSTIN, TEXAS 4·21·67 WEIDMAN/SL

TRACOR 6500 TRACOR LANE, AUSTIN, TEXAS 78721

CTT

PURPOSE: This function subprogram computes the next time to turn for the Penetrator on his evasive course.

INPUT:

TIME = Time (min)

OUTPUT:

Value of the function CTT = Time to turn

INTERNAL CONSTANTS:

Penetrator maneuver frequency = 5 minutes

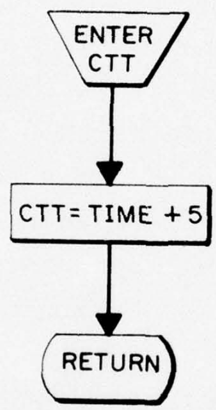

FIG. A-26 – CTT FLOW CHART

TRACOR, INC. DWG. A6-62-254
AUSTIN, TEXAS 4-21-67 WEIDMAN/SL

TRACOR 6500 TRACOR LANE, AUSTIN, TEXAS 78721

FIRCON

PURPOSE: This program attempts to determine a fire control quality track of the target. This is accomplished by fitting a least squares line to the X and Y motion of the target, independently. This routine assumes constant velocity motion by the target.

INPUT:

RHO	=	Range from the ranging subsystem (yds)
THETA	=	True bearing of other boat from the bearing subsystem (radians)
XO	=	X-coordinate of own ship's estimate of own position in an Earth-fixed coordinate system (yds)
YO	=	Y-coordinate of own ship's estimate of own position in an Earth-fixed coordinate system (yds)
IPINT1	=	Number of points in the current track
TIME	=	Time since the beginning of the simulation (min)

OUTPUT:

ALPHA = Array of four parameters to characterize motion of target

$$X = \alpha_1 + \alpha_2 t$$

$$Y = \alpha_3 + \alpha_4 t$$

SIGMA	=	Array of standard deviations of $X(\sigma_1)$ and $Y(\sigma_2)$' values about the least squares lines (yds)
IFLAG	=	Array of two tracking flags to indicate whether track is of sufficient quality to launch a weapon
XEST	=	Current estimate of target's X-position in Earth-fixed coordinate system
YEST	=	Current estimate of target's Y-position in Earth-fixed coordinate system
TLAST	=	Time when track was last updated (min)

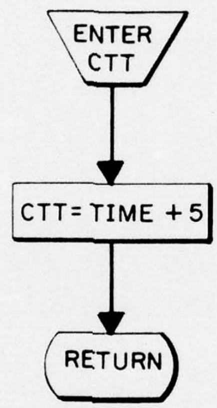

FIG. A-26 – CTT FLOW CHART

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INTERNAL VARIABLES AND INTERNAL CONSTANTS:

IPINT2 = Internal flag used to determine if track is to be updated

XKNYPM = Conversion factor from knots to yards per min

K = Dimensioned array of variables against which SIGMA is compared to determine if tracking flag IFLAG should be set

XUMXSQ = ΣX_i^2

SUMXT = $\Sigma X_i t_i$

SUMX = ΣX_i

SUMT = Σt_i

SUMTSQ = Σt_i^2

SUMYT = $\Sigma Y_i t_i$

SUMY = ΣY_i

SUMYSQ = ΣY_i^2

$X_i = X_o + \rho \sin\theta$

$Y_i = X_o + \rho \cos\theta$

$t_i = \text{TIME} - \text{TSTART}$

N = Number of points in current track

(All sums are taken from i = 1 to i = N.)

B = Range between boats

CXCA = Velocity necessary to intercept target boat on a $\perp$ course (kts)

ALF = Interior angle of close and attack triangle at target position

BETA = Interior angle of close and attack triangle at own ship position

T2 = Intermediate variable used to compute final heading which assures that the Barrier Boat always leads the target.

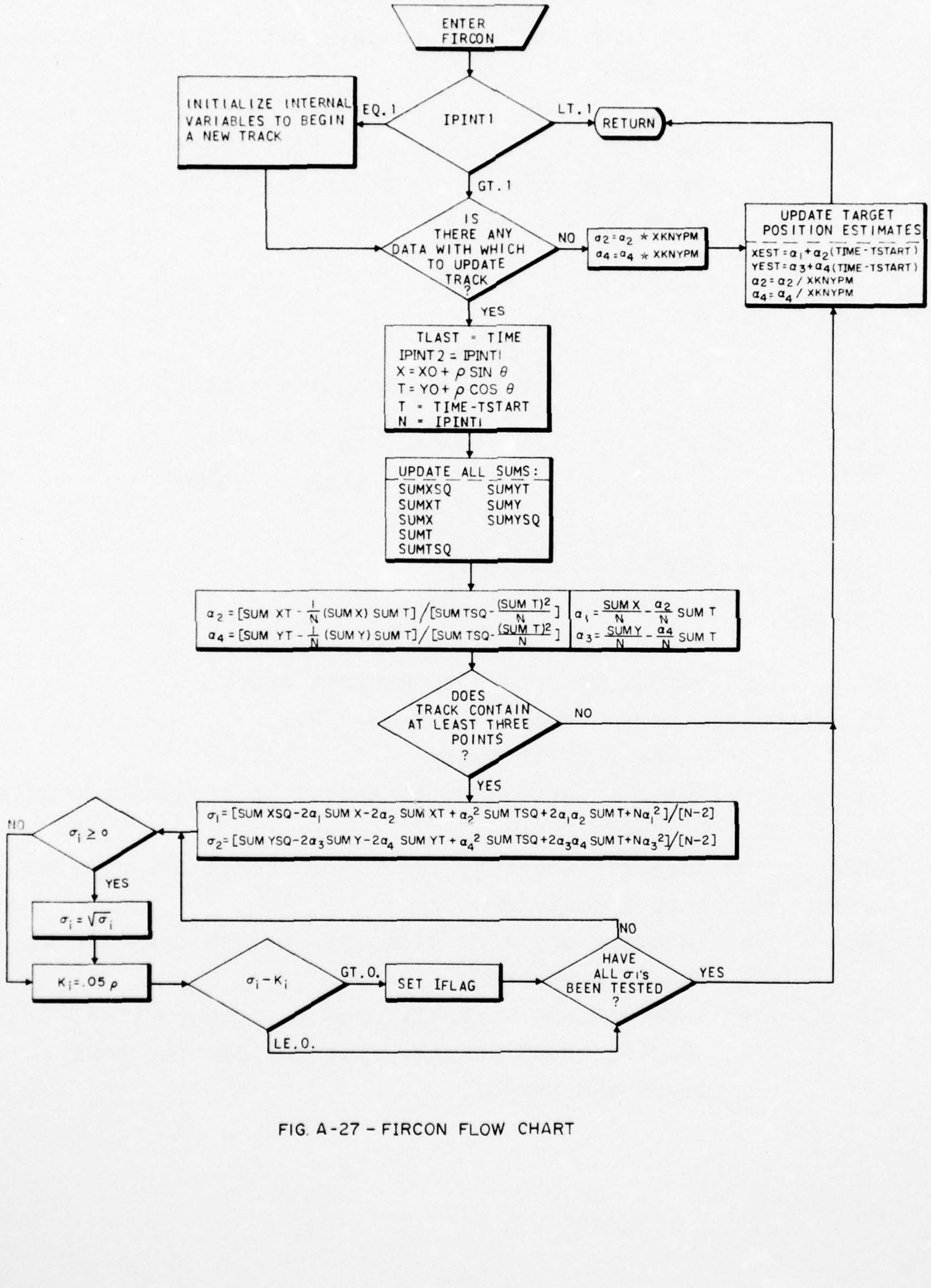

FIG. A-27 - FIRCON FLOW CHART

TRACOR, INC DWG 86-62-294
AUSTIN, TEXAS 5-2-67 WEIDMAN

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PHICA

PURPOSE: This routine computes the heading for the Barrier Boat which permits him to intercept the enemy in the close and attack situation (TS9). The heading is also chosen subject to the constraint that PUFFS be able to effectively bear on the target.

INPUT:

(X1,Y1)	=	Current position of Barrier Boat in the barrier coordinate system
C_1	=	Speed of Barrier Boat (returned as speed with which boat proceeds to intercept) in knots
(X2,Y2)	=	Current position of target in the barrier coordinate system
C_2	=	Speed of target boat (kts)
PHI2	=	Heading of target
PHIT	=	Last true bearing of target reported by bearing subsystem

OUTPUT:

PHICA	=	Heading of Barrier Boat to effect intercept (radians)
C1	=	Speed to intercept (kts)

INTERNAL VARIABLES AND ARBITRARY CONSTANTS:

X	=	Relative X-separation of boats
Y	=	Relative Y-separation of boats
A	=	The dot product of the relative position vector and the target velocity vector

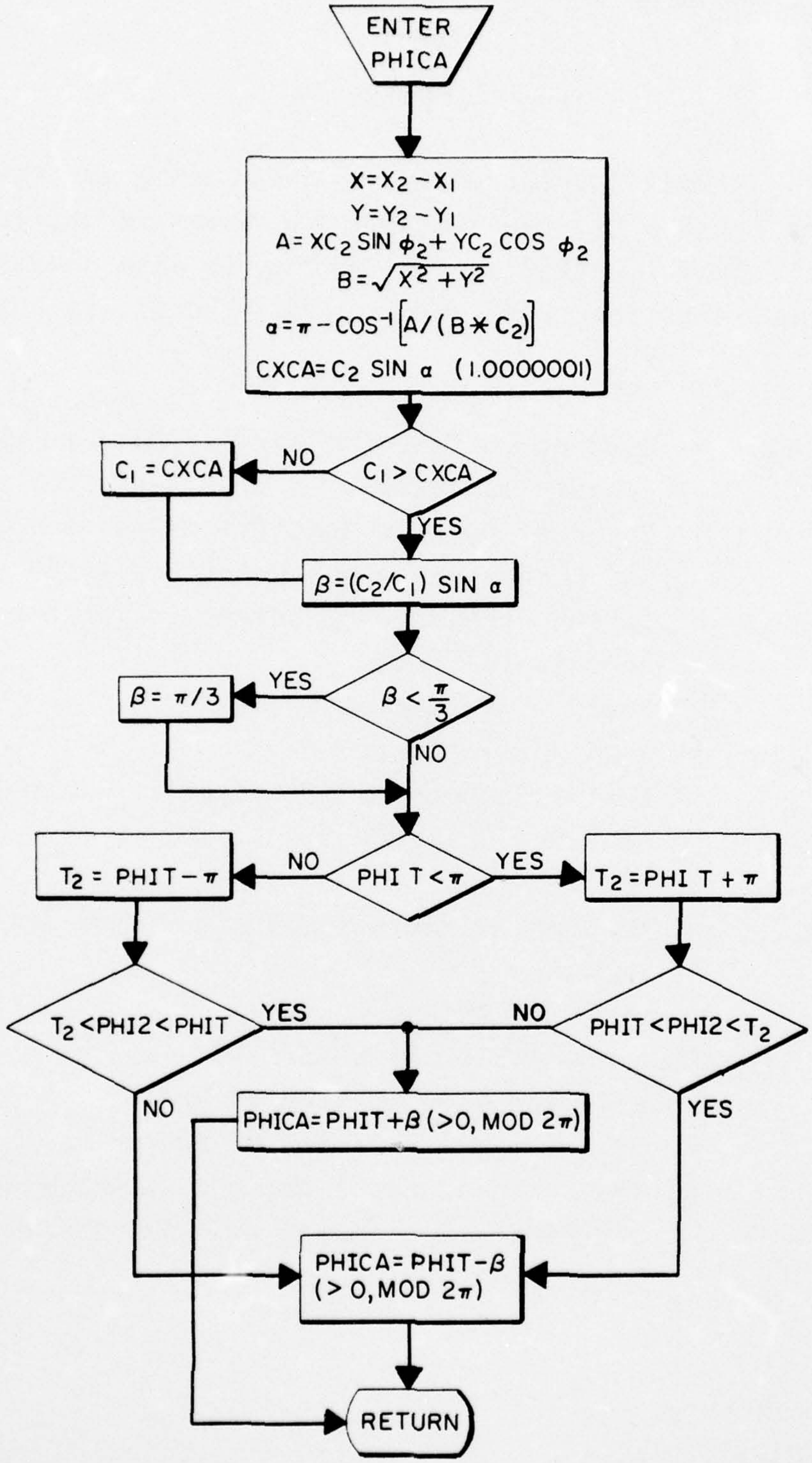

FIG. A-28 – PHICA FLOW CHART

TRACOR, INC. DWG. A6-62-253
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SNORK1

PURPOSE: This routine is called when it is time for any boat to snorkel. The routine adjusts the depth and initiates the snorkeling. The routine calls ATSS to set the next snorkel time.

INPUT:

T	=	Time
Z2	=	Depth at which boat snorkels (yds)
C2	=	Speed at which boat snorkels (kts)
I2	=	Index number of boat

OUTPUT:

Z1	=	Current Depth of boat
C1	=	Current speed of boat
I1	=	Flag to indicate whether or not boat is snorkeling 0 = No, 1 = Yes
T3	=	Next time to start snorkeling

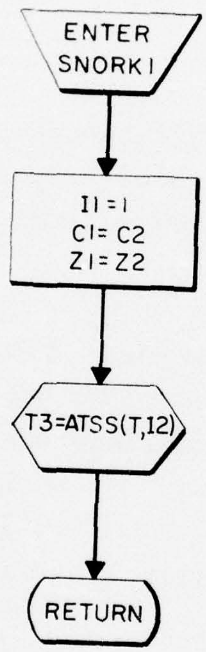

FIG. A-29 — SNORK1 FLOW CHART

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SNORK2

PURPOSE: This routine is called when it is time for a boat to cease snorkeling. It adjusts the depth and speed to those read in as appropriate to the boat, and sets the next time to cease snorkeling by calling ATCS.

INPUT:

T	=	Time
Z2	=	Depth for boat after snorkeling (yds)
C2	=	Speed for boat after snorkeling (kts)
I2	=	Index number of boat

OUTPUT:

Z1	=	Current depth of boat
C1	=	Current speed of boat
I1	=	Flag to indicate whether boat is snorkeling or not 0 = No 1 = Yes
T1	=	Next time for boat to cease snorkeling
T2	=	Time when boat last completed snorkeling

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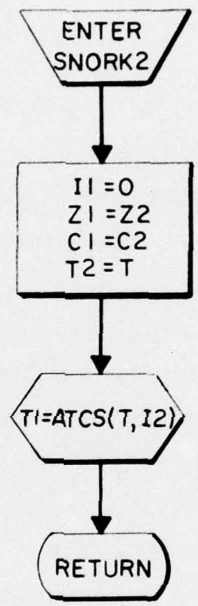

FIG. A-30 — SNORK2 FLOW CHART

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SSAMB

PURPOSE: This subroutine determines if the Barrier Boat can ambush an enemy Diesel-Electric boat based on the information currently available to the Barrier Boat. If the ambush can be consumated, the routine returns the parameters to guide the Barrier Boat to the ambush position.

INPUT:

R	=	Current estimate of the target position vector in barrier coordinates
V	=	Current estimate of the target velocity vector in barrier coordinates (kts)
T	=	Time
VC	=	Minimum speed at which Barrier Boat will attempt to ambush (returned as speed at which Barrier Boat will actually proceed to ambush) in kts
DWR	=	Barrier Boat detection range (yds)
TEST	=	Estimated time from present when target will snorkel (min)
CMAX	=	Maximum speed of Barrier Boat (kts)
RHO	=	Current estimate of the relative position vector from Barrier Boat to target in barrier coordinates (yds)
XMAN	=	Minimum and maximum values of X-coordinate inside which Barrier Boat must maneuver
YMAN	=	Minimum and maximum values of Y-coordinate inside which Barrier Boat must maneuver

OUTPUT:

ALPH	=	Heading to be assumed upon reaching ambush pivot point (radians)
BETA	=	Angle between present heading and ambush heading for Barrier Boat (radians)

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TSTOP	=	Time from beginning of simulation when Barrier Boat will reach ambush pivot point (min)
TWAIT	=	Time from beginning of simulation when target will enter Barrier Boat's detection range EWR after Barrier Boat reaches ambush pivot point (min)
JFLGSS	=	Flag for ambush 0 = can ambush 1 = cannot ambush

INTERNAL VARIABLES AND ARBITRARY CONSTANTS:

XKNYPM	=	Conversion factor from knots to yards per minute
DELT	=	Time step for incrementing ambush calculation
D2	=	Length of target leg of triangle for time TEST
D1	=	Length Barrier Boat leg of triangle for time TEST
V2	=	Estimated speed of target boat (yards per minute)
(XE,YE)	=	Vector of estimated target position at time TEST from present
DTEST	=	Length of the sum of the vector RHO and a vector of length D2 with direction of V
RHOMAG	=	Magnitude of RHO
C1	=	X-component of vector along V with magnitude D2
C2	=	Y-component of vector along V with magnitude D2

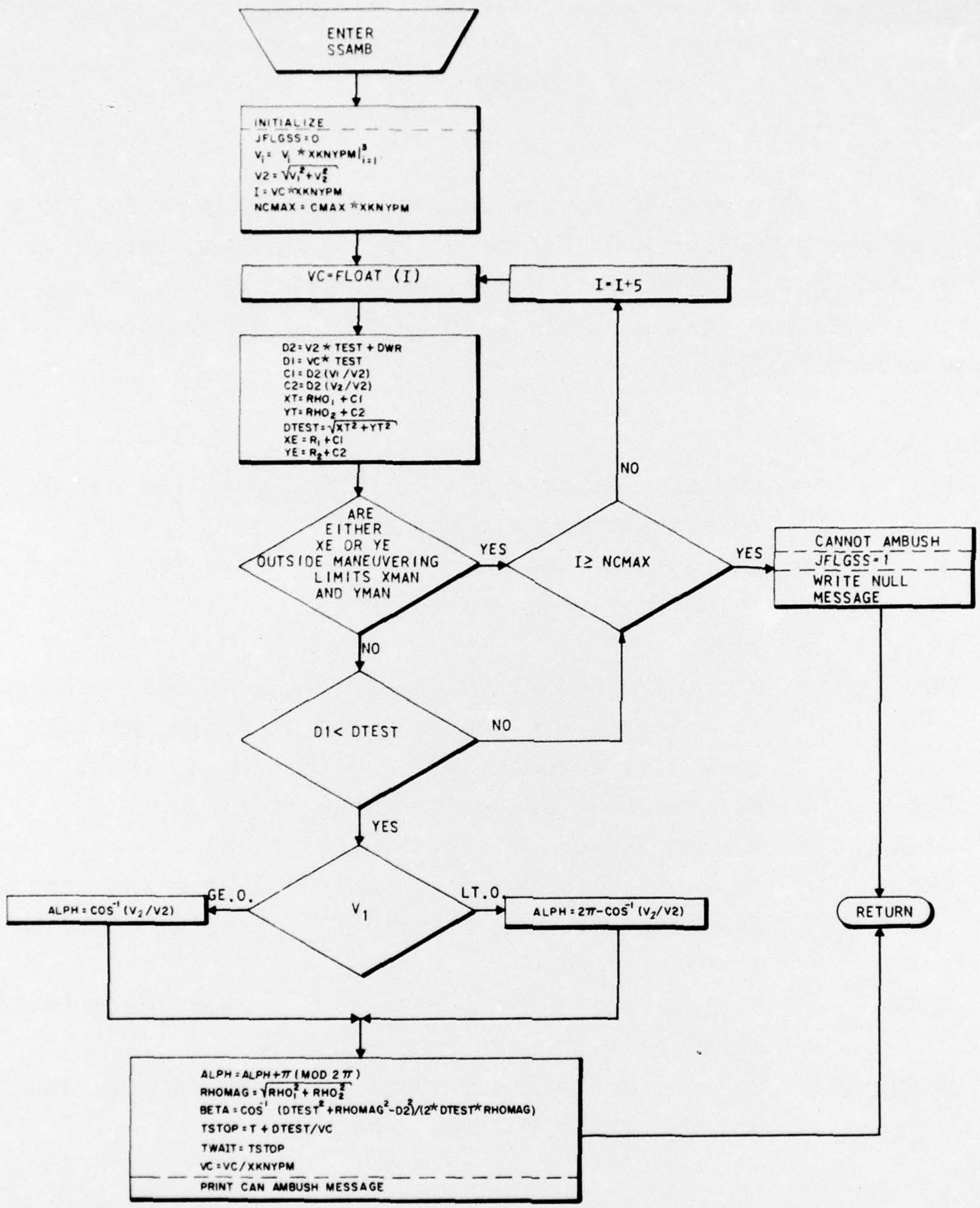

FIG. A-31 –SSAMB FLOW CHART

TRACOR, INC DWG 86-62-299
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SSNAMB

PURPOSE: This subroutine determines if the Barrier Boat can ambush an enemy Nuclear boat based on the information currently available to the Barrier Boat. If the ambush can be consumated, the routine returns the parameters to guide the Barrier Boat to the ambush position.

INPUT:

R	=	Current estimate of the target position vector in barrier coordinates (yds)
V	=	Current estimate of the target velocity vector in barrier coordinates (kts)
T	=	Time
VC	=	Minimum speed at which Barrier Boat will attempt to ambush (returned as speed at which Barrier Boat will actually proceed to ambush) (kts)
DWR	=	Barrier Boat detection range (yds)
CMAX	=	Maximum speed of Barrier Boat (kts)
RHO	=	Current estimate of the relative position vector from Barrier Boat to target in barrier coordinates (yds)
XMAN	=	Minimum and maximum values of X-coordinate inside which Barrier Boat must maneuver
YMAN	=	Minimum and maximum values of Y-coordinate inside which Barrier Boat must maneuver

OUTPUT:

ALPH	=	Heading to be assumed upon reaching ambush pivot point (radians)
BETA	=	Angle between present heading and ambush heading for Barrier Boat (radians)
TSTOP	=	Time from beginning of simulation when Barrier Boat will reach ambush pivot point (min)

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TWAIT	=	Time from beginning of simulation when target will enter Barrier Boat's detection range EWR after Barrier Boat reaches ambush pivot point (min)
JFLGSN	=	Flag for ambush 0 = can ambush 1 = cannot ambush

INTERNAL VARIABLES AND ARBITRARY CONSTANTS:

XKNYPM	=	Conversion factor from knots to yards per minute
DELT	=	Time step for incrementing ambush calculations
D2	=	Length of target leg of triangle for time TEST
D1	=	Length of Barrier Boat leg of triangle for time TEST
V2	=	Estimated speed of target boat (yds per min)
(XE,YE)	=	Vector of estimated target position at time TEST from present
D	=	Length of the sum of the vector RHO and a vector of length D2 with direction of V
RHOMAG	=	Magnitude of RHO
C1	=	X-component of vector along V with magnitude unity
C2	=	Y-component of vector along V with magnitude unity
ALPH	=	Internal angle in triangle opposite Barrier Boat leg
C	=	Horizontal range between boats
TO	=	Time from present for which boat motions are extrapolated
D2PRM	=	Initial estimate for length of target leg of triangle (yds)

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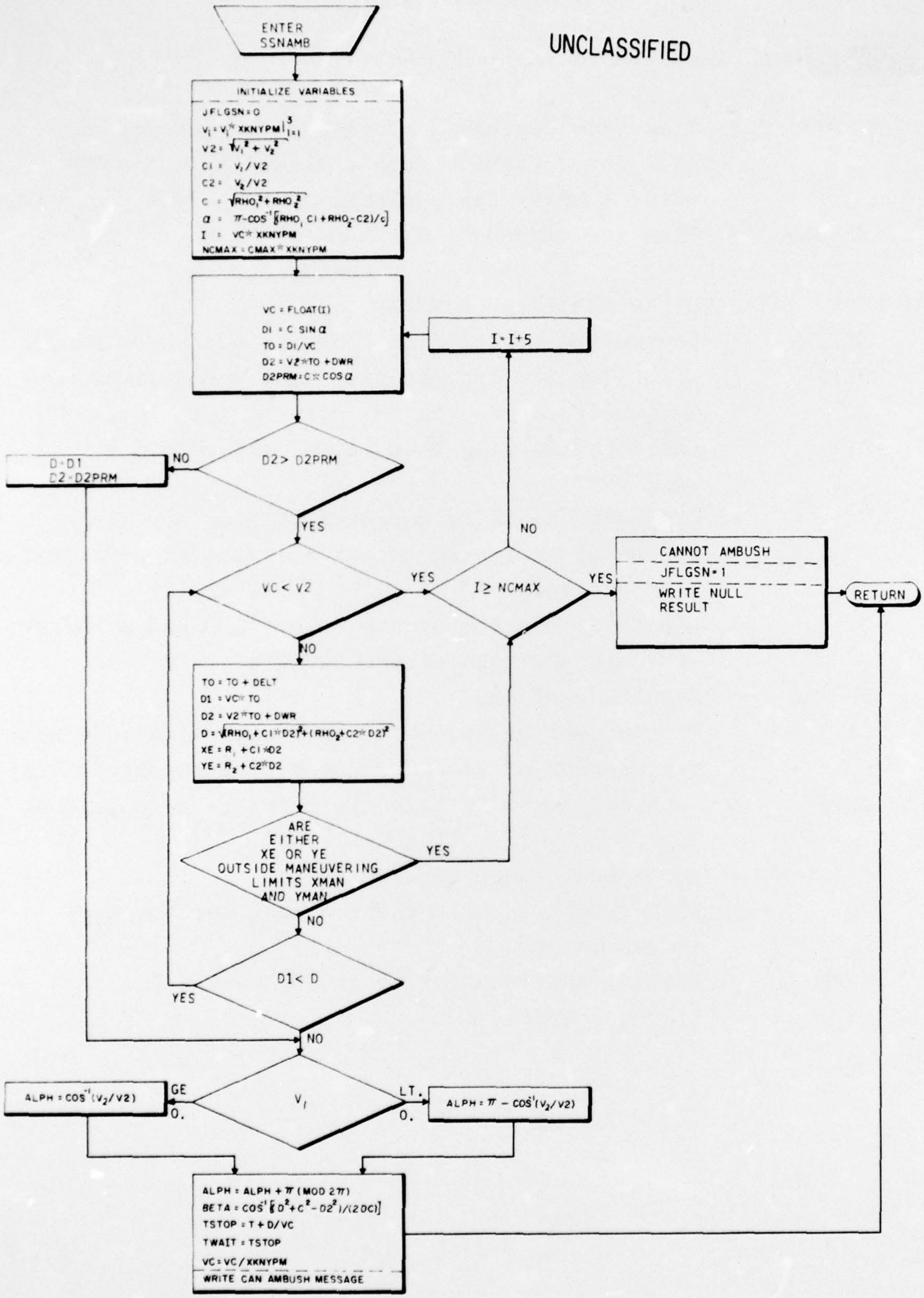

FIG. A-32 — SSNAMB FLOW CHART

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TRACK

PURPOSE: This program attempts to determine a base course for a maneuvering target. This is accomplished by fitting a least squares line to the X and Y motion of the target, independently. The routine assumes constant velocity motion in both X and Y by the target.

INPUT:

RHO	=	Range from the ranging subsystem (yds)
THETA	=	True bearing of other boat from the bearing subsystem (radians)
XO	=	X-coordinate of own ship's estimate of own position in an Earth-fixed coordinate system (yds)
YO	=	Y-coordinate of own ship's estimate of own position in an Earth-fixed coordinate system (yds)
IPINT1	=	Number of points in the current track
TIME	=	Time since the beginning of the simulation (min)

OUTPUT:

ALPHA = Array of four parameters to characterize motion of target

$$X = \alpha_1 + \alpha_2 t$$

$$Y = \alpha_3 + \alpha_4 t$$

SIGMA = Array of standard deviations of $X(\sigma_1)$ and $Y(\sigma_2)$ values about the least squares lines (yds)

IFLAG = Array of two tracking flags to indicate whether track is of sufficiently good quality to launch a weapon

XEST = Current estimate of target's X-position in Earth-fixed coordinate system

YEST = Current estimate of target's Y-position in Earth-fixed coordinate system

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TLAST = Time when track was last updated (min)

INTERNAL VARIABLES AND INTERNAL CONSTANTS:

IPINT2 = Internal flag used to determine if track is to be updated

XKNYPM = Conversion factor from knots to yards per min

K = Dimensioned array of variables against which SIGMA is compared to determine if tracking flag IFLAG should be set

TSTART = Time initial data on current track was accrued

SUMXSQ = ΣX_i^2

SUMXT = $\Sigma X_i t_i$

SUMX = ΣX_i

SUMT = Σt_i

SUMTSQ = Σt_i^2

SUMYT = $\Sigma Y_i t_i$

SUMY = ΣY_i

SUMYSQ = ΣY_i^2

$X_i = X_o + \rho \sin\theta$

$Y_i = X_o + \rho \cos\theta$

t_i = TIME - TSTART

N = Number of points in current track

(All sums are taken from i = 1 to i = N)

TTRACK = Length of time for which data must be accumulated before a base course for the target can be predicted (min)

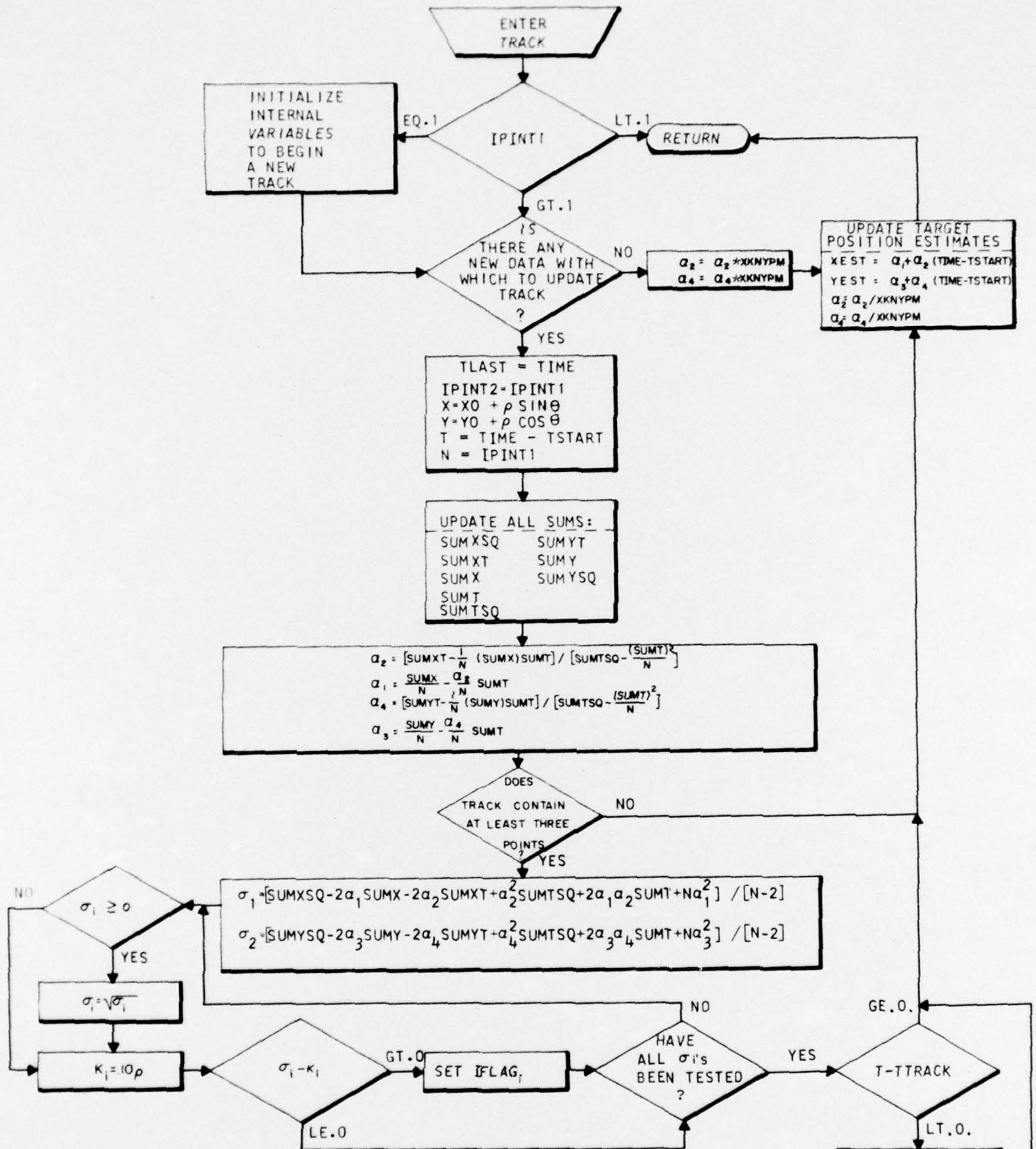

FIG. A-33 - TRACK FLOW CHART

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13. ABSTRACT

In the front portion of this Technical Memorandum, the general approach to the complete digital computer simulation of Anti-Submarine Warfare (ASW) Combat is formulated and discussed. The discussion centers upon the three basic components of combat—command and control functions, machines and the environment—and identifies the general parameters and dynamic variables required to simulate these components. (While the primary concern is ASW combat, the general principles are applicable to any type of combat). The second portion of this memorandum presents a detailed discription of the simulation of combat between two submarines. In this simulation one submarine is deployed on a Forward Area Patrol Mission. The mission of the second submarine is to transit the patrol area of the first submarine. This digital computer simulation contains many features discussed in the general approach and demonatrates the feasibilty of constructing a general ASW Combat Simulation for a digital computer.

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